Evaluating the learning outcomes and program format of the science education programs for school groups at the CSIRO Discovery Centre (Canberra)

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Acknowledgements and Dedication

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Thank you one and all.

Declaration

I declare that this sub-thesis is my own work and all sources have been acknowledged. I certify that this thesis does not incorporate, without any acknowledgement, any material previously submitted for a degree or diploma at any university, and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except when due reference is made in the text.

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For learning to take place with any kind of efficiency students must be motivated. To be motivated, they must become interested. And they become interested when they are actively working on projects which they can relate to their values and goals in life.

Gus Tuberville, President, William Penn College

"I was impressed with the amount of knowledge the children retained, as we visited CSIRO 17 weeks ago." Teacher, Year 6

Abstract

Science centres are places of informal learning where people visit usually with the intention of finding out about science. Many of these science centres conduct school education programs as a means of communicating scientific information to school students. Previous research has shown that learning does occur during these science centre visits, and this paper looks at the efficacy of the school education programs at the Discovery Centre in Canberra. By exploring the learning outcomes and format of these programs this paper examines whether the objectives of the program are met and what factors may influence this learning episode. Of greatest interest is the reflection on, and recollection of, information learned from the science education experience and students' enjoyment levels of the program.

Data was collected by survey questionnaire, administered to the students and teacher of each class. Results are based on classes as the unit of analysis and show a high level of information retention and interest in science. Results also showed that these programs met the objectives set for them, with most student groups recalling their science education program experience and enjoying the participatory style of the programs. Additionally, results indicated a heightened awareness about the complexities of the practice of scientific research, its related decision-making and its role in society.

Chapter 1: INTRODUCTION

Science centres[1] are places that people visit, usually with the intention of finding out something about science. Whether that is a visitor's intention or not, that is the hope of the science centre – to communicate some information about science. Though they may have changed over the past century, and the experience vary dramatically from place to place – from the 'good old days' of staring at unrecognisable species of stuffed animals in glass cabinets, to hypnotically staring at intriguing fishes in decorative floor-to-ceiling tanks, to the now whiz bang, bedazzling, entertaining, button-pushing, lever-moving exhibits of many contemporary science centres – they are all about the same thing: science.

But do these places actually successfully convey any science information to their visitors? Does looking at aesthetically pleasing fishes with pleasant background music playing, or pushing a button to create a mini earthquake really bestow science information upon the science centre visitor? Maybe some just do it better than others, or, maybe there is a formula for success? Whatever the answer, the question is, do science centres successfully communicate science information?

It is general belief that science centres are places where learning occurs and knowledge is acquired – one of the reasons why people visit them. For decades they have enticed teachers and school students to visit on field trips, to enhance or reinforce their formal education at school. Now, many science centres run education programs specifically for school groups, in the hope (by both teachers and science centres) that some learning will occur.

In this paper, the question of learning experiences in science centres is explored by looking at the design and intended outcomes of the science education programs at one particular science centre. But first, a little bit of history.

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[1] In this paper, the term 'science centre' is used to collectively refer to all institutions that are science-based, such as science and technology centres, museums, zoos, botanical gardens, aquariums and planetariums/space centres.

1.1 A little bit of history

Science centres, as we know them, are one type of public facility that has evolved out of the broader category of museums. It appears that the first function of museums was for collection – to preserve objects of artistic, historic and scientific importance for the enlightenment and enjoyment of present and future generations (Alexander, 1980). These collections existed because their contents were deemed important and evocative survivals of human civilization worthy of careful study and powerful educational impact (Alexander, 1980). The many carefully preserved items, which tell much about nature, the universe and the human condition, transmit important information to the present generation and posterity (Alexander, 1980).

Starting from the Renaissance, those of the upper echelons of society had various collections on display to show associates, and universities and medical schools had large collections of specimens for study. From these collections, natural history museums evolved during the nineteenth century, and in the late 1800s and on into the beginning of the twentieth century, science museums started to emerge, predecessors of modern science centres.

The Deutches Museum in Munich, built in 1903, was probably the first true science centre as we define them today, which included some interactive exhibits. The German science centre is said to have inspired the creation of the Museum of Science and Technology in Chicago, built in the 1930s. Later that century, the Ontario Science Centre opened in 1967, and then Frank Oppenheimer's Exploratorium in 1969. Since then, science centres have become popular in modern society as a place to go to learn about science.

From their original purpose of preserving and presenting human history, science centres now have other purposes, importantly, the role of effective communication. As science centres have grown in popularity, so too have expectations for their ability to do more than just exist to display science for observation. Expectations to provide an educative role in society started to grow during the first half of the twentieth century (Hein, 2000).

During this time, there was extensive experimental work on learning and perception carried out in growing educational psychology departments (Hein, 2000). This started changing the views of many towards supporting the notion of an educational function for museums. At the same time, the connection between schools and museums was reinforced by the development of museums within school systems (Rathman, 1915, in Hein, 2000), and their association with school activities (Coleman, 1939, in Hein, 2000)

Today, many science centres conduct education programs as alternatives to curriculum-driven formal school systems. Although programs may enhance school curricula, they are places of informal learning, not bound to school agendas. There is a substantial collection of research that indicates learning takes place in science centres, and to varying degrees in school education programs.

This paper looks at the learning outcomes of the education programs at one particular science centre – the Discovery Centre (Discovery) in Canberra, Australia. Discovery is part of the federal Commonwealth and Industrial Research Organisation (CSIRO). The objectives of the science education programs at Discovery (as set by the program creators) are to raise awareness of CSIRO, scientific research and the benefits of it, in school age students, and, engage them in a scientific funding decision-making process. So, do students learn any science information after participating in these programs? And if so, what is it that they learn? There is much anecdotal evidence suggesting that there is learning going on, however, these questions have not been examined formally. This research assesses the type of information that students recall, the level of students' enjoyment of these programs and explores the role of the program format in the learning experience. Does it positively affect the process of learning during these programs?

1.2 Background

The CSIRO 's Discovery Centre (Discovery) is a public science facility, located in Canberra, opened in August 2000. It is part of the division of Plant Industry of CSIRO and is housed in the Discovery building at the Black Mountain site. The building is designed to facilitate public accessibility to science. It includes functioning gene technology laboratories, with glass walls to enable visitors to view scientists at work, and the Discovery centre – which displays information about CSIRO research and hosts school education programs.

1.3 Objectives and Philosophy of the DSIS Programs

Discovery's school education programs are called 'Discovering Science in Society' (DSIS). They are available for both primary and secondary school students, from all states and territories of Australia. The content and structure of these programs are designed with the intention of effectively meeting certain objectives.

The DSIS program objectives, as stated by the program creators and manager of the Discovery Centre, Ms Christine Cansfield-Smith, are:

- to raise awareness of CSIRO amongst school-age children;
- to engage students in a scientific funding decision-making process, and
- raise awareness of scientific research, and its benefits, amongst school-age children.

The philosophy of the education programs is to showcase CSIRO research and present contemporary science research in an engaging, exciting and interactive format. The programs try to counterbalance the frequently presented image of science being fun, bubbles, mirrors and liquid nitrogen, by making science relevant. Hence, the programs are developed to portray the importance and relevance of science research, explaining the science behind the research, rather than presenting the 'mad scientist' working with chemicals in a laboratory.

The education programs are therefore designed to expose students to CSIRO, explain some past and current research undertaken by CSIRO in scientific terms – how it is conducted, issues associated with conducting research, results and implications of the research – and involve students in a number of science-related activities.

1.4 'Discovering Science in Society' School Education Programs

Upon arrival at Discovery, visiting students are assembled in an 'Education Room' where they are welcomed, introduced to the staff who will be working with them and familiarised with what the education program entails and what they will be doing.

The DSIS programs are 90 minutes in duration and involve students in a variety of learning activities. Students are divided into groups of around 10-15 students for each activity, with the aim of encouraging optimal learning and manageability. The activities include a role-play scenario involving the delivery of information about current CSIRO research; watching visual media; listening to information about various CSIRO projects and spending time in a mini-laboratory, performing simple experiments. Additionally, if time allows, some groups are also able to handle some live creatures (stick insects and mice) as an extra activity. The program developers consider the mental activity of the role-play scenario to be a 'minds-on' activity, and the activities in the laboratory as 'hands-on'.

The majority of time is spent on the 'minds-on' scenario. For this role-play activity students assume the role of an organisation, or private company, with funds available to invest in a CSIRO research project[2]. Each group is presented with information on two different research topics (current CSIRO projects) that need funding in order to begin or continue its work. Information about the nature of the research; the methodology and science involved; the intended purpose of performing such research, and the desired outcome or demonstrated application is explained. After each body of

[2] At the time of this research, approximately 40% of funding for CSIRO research was derived from the private sector.

information is presented, students are requested to vote for which research project they wish to fund.

Some research areas presented at the time of this data collection (2005), included gene technology, food technology and ecological research. Gene technology covered the use of genetic modification in plants or animals to determine a particular beneficial outcome. For example, genetic modification of cowpea plants to protect plants from insect damage and crop loss. Food technology covered aspects of food use and development for medicinal purposes. For example, extracting substances from particular foods to be used in food supplements for health benefits and disease protection. Ecological research included environmental issues and the research used to solve these problems. For example, manipulation of cane toad lifecycles to reduce population numbers, and the use of 'indicator species' in determining native species loss and environmental degradation. These topics change approximately every six to nine months to maintain contact with updates within current research, or to showcase new research projects.

Photo 1:
Students exploring the Biodiversity display as part of the presentation talks on science research

Presenters encourage students to interact with them during the role-play talk. The topics are chosen to provoke questioning, encourage discussion or debate and challenge students to think about the science performed and choices involved in prioritising research. Often the research topics directly affect some students – such as salinity issues and re-vegetation of farms may affect students and their family or community in rural areas, or, the eradication of cane toads in Queensland, as some students may have these animals in their schools or backyards. As a result, discussions can become quite passionate about some of the issues raised by the research.

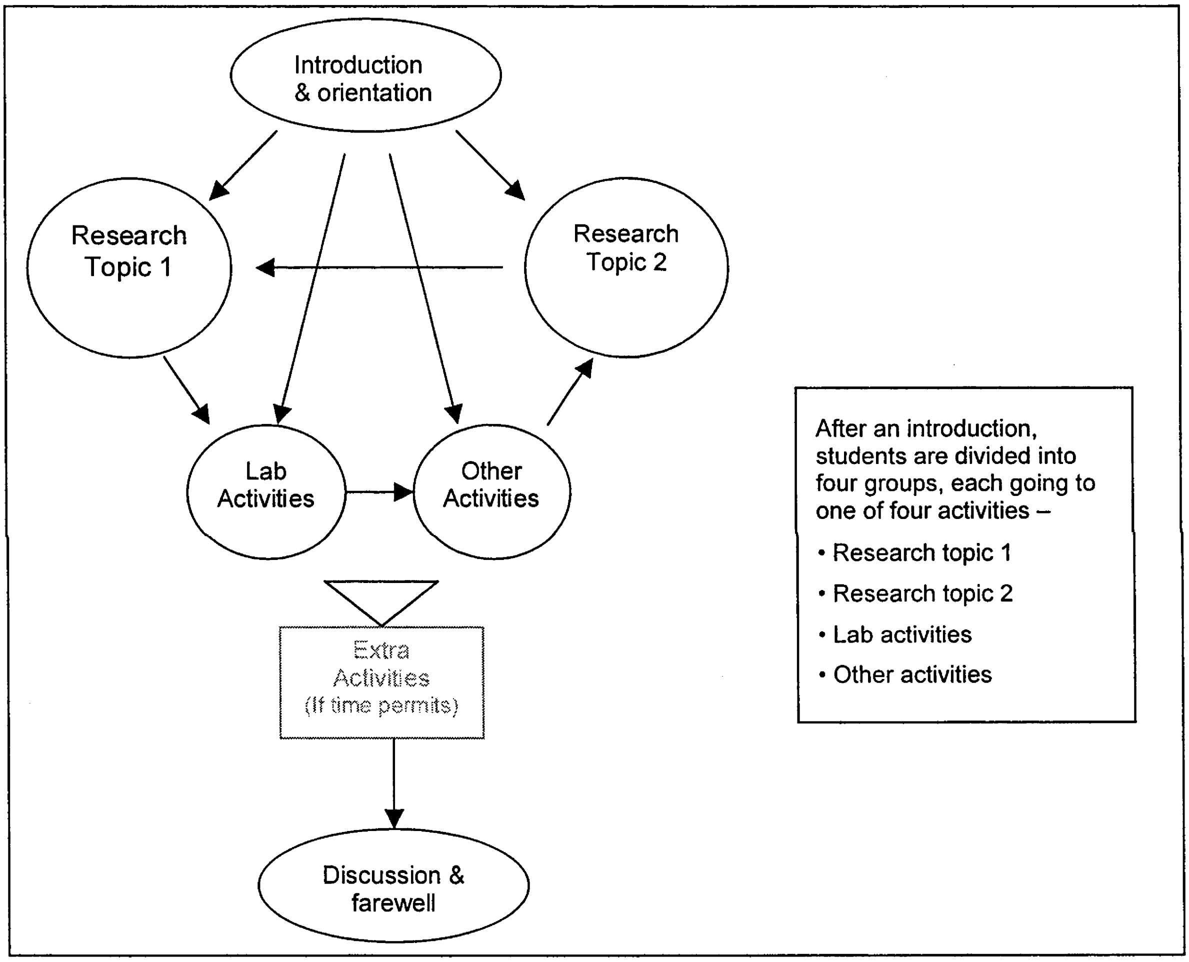
Photo 2:
Students asking questions during a presentation about science research

By assigning decision-making responsibility to the students, they are incorporated into an experience that demonstrates one of the processes of decision-making regarding scientific research. This responsibility stimulates the students to consider and evaluate issues such as urgency, priority, economics, ethics, safety, society and the environment related to the scientific research presented to them. In the process of voting for their preferred research topic students choose between the two projects based on these issues. For example, they may have had to decide whether salinity issues and degradation of farming land in Australia is a more urgent problem and in greater need of funding than a humanitarian project that involves genetic manipulation of plants to feed people in Africa. Another example would be the choice between research involving eradication of cane toads and food technology research used to create disease-preventing food supplements. Some questions they may have considered before casting a vote are:

- Who will benefit from the research?;
- How wide-spread are the benefits?;
- Are there any negative consequences of the research?;
- How does it affect me, my family and community?;
- How much will it cost?;
- Does it affect the environment?, and
- How important is this research?

Once votes were cast and tallied, students were asked about their choice of one research topic over the other and the decision-making process involved. This was a voluntary process in which students chose whether they wanted to offer this information to staff. However, most groups were eager to impart their rationale or reasoning about how they came to their individual voting decision.

Figure 1: Flow diagram of program format and activities



After this focused 'minds-on' activity, students moved on to the other activities in the program. This included time in the mini-laboratory performing small experiments such as making cheese with milk and rennet; using colour indicators to determine the pH of unidentified solutions; looking through microscopes; extracting DNA material from pea plants and testing the different levels of protection between sunscreen creams under UV light. During this part of the program, students are free to choose what they want to do. They are encouraged to function autonomously, follow written instruction and use their own problem-solving abilities, only requesting assistance where necessary. However, staff do assist various students with their activities and explain the science behind the activities. Other activities included viewing a short three-dimensional film (with 3D glasses) about some scientific research, freely wandering through other exhibits or handling live creatures.

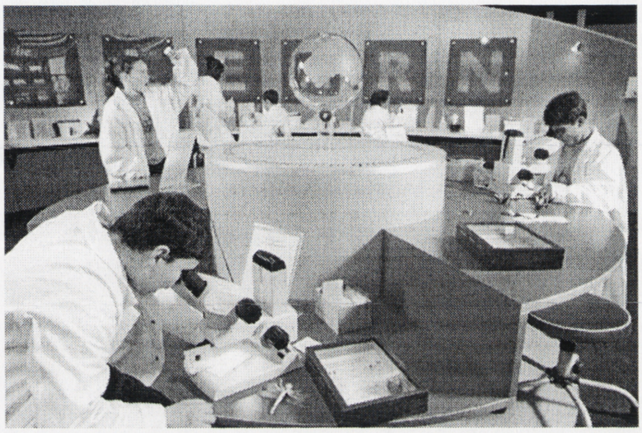


Photo 3:
Students involved in the mini-lab activities during the education program

All activities within the DSIS program impart scientific information to students through a participatory, active and enquiry-based approach. They are designed to be most effective for small groups; ideally for students between the ages of 10 and 15. However, programs can be modified to suit the age or ability of each group by adding or removing information, adapting specific tasks or changing the duration of activities.

The program format specifically incorporates a variety of activities within each session. Each group of students moves from one activity to the next within approximately 20 minutes, which is intended to maintain student attention and interest in each topic. It is likely that this intention creates an environment that encourages learning and caters for different learning styles among students, as some students may learn by listening, discussing and questioning, while others through investigation, observation or tactility.

That learning experience, within the DSIS programs, is the object of this research paper. Are these programs effective forms of science communication resulting in learning?

1.5 Research Problem

The research problem being explored is whether the DSIS education programs are an effective[3] form of science communication. Education programs are often assumed to be effective forms of science communication, hence their existence, and in this case anecdotal evidence[4] suggests the DSIS programs are effective. However, no previous research has formally assessed their learning outcomes.

This paper looks at the success of dissemination of scientific information through these programs, and whether the format is a determining part of their efficacy. Learning outcomes are evaluated and the influence of the program format is assessed.

Of most interest to this research is the type and quantity of scientific information absorbed by students. Do the students leave with an understanding of the CSIRO and the research it undertakes? And, do they gain any other knowledge about science from the information that is presented, or to which they are exposed, during their visit?

If students do learn from these programs, do they retain this information? Are these transient moments of knowledge acquisition, or do they have a more significant impact and holistic affect on learning about science? To determine the possible retention of learned information, assessment was made in a period of 8-20 weeks after completing the education programs. As students demonstrated enthusiastic initial

[3] In this paper, effective refers to successfully meeting the goals set for the DSIS programs – to learn about the CSIRO, the relevance of scientific research and engage students in a funding decision-making process. It also includes the acquisition of any other information about science by students.

[4] Observed behaviour in students during 2004-05, in which time the author was employed as a CSIRO Discovery DSIS education officer for school education programs

recall of information learned immediately upon completion of the DSIS programs, the author was interested in ascertaining for how long this may be retained.

The format of the programs is designed to be varied, participatory and enquiry-based, which seemed to be favourable with the majority of participating students. The author believed this particular format had an influence on the learning experiences, therefore, student responses about the format of the programs were recorded and evaluated.

Participating students come from various learning levels and backgrounds of prior scientific knowledge. Therefore students' absorption and retention levels will vary. This variation has been considered and addressed in the number and variety of students in the sample group.

The purpose in analysing the learning outcomes of these education programs is to assist understanding in communication of science knowledge through such education programs. Looking at the structure and program format helps determine whether this is a factor affecting learning outcomes. These analyses may assist with the creation or design of future science education programs. They may be maintained or modified as a result of these findings.

Further to that, this research may also give impetus to investigation into how such learning outcomes affect, or are applied to, a student's life following their visit. That is, how the role of science education programs such as this one, and this type of learning experience, may influence a student's future understanding of science. These findings may also encourage continued research that looks more closely at the process by which individuals learn in such an informal environment. This sort of education program is of course designed to be a learning experience, but there is a range of learning outcomes that result from participation in these programs.

1.6 Research Questions

The following questions assess the learning outcomes and program format in order to address the research problem.

1. Do the education programs fulfil the objectives set for them? (As stated on p.5)
2. Do participating students enjoy the activities/format of the education programs?
    2.1. If so, does the format have an effect on student learning?
3. Do the participating students learn any scientific information?
    3.1. If so, what scientific information do students learn?
    3.2. If learnt, how long do students retain the scientific information?

1.7 Summary

This thesis looks at the efficacy of science education programs at CSIRO Discovery as a form of science communication. It evaluates the learning outcomes of the programs and explores whether the program structure contributed to the results.

Data was collected in the form of a survey. Questions were asked to students and their teachers about their experience of the education program. Each survey contains answers that have been compiled as a group response from each group of students.

The following chapters look at some of the associated literature on learning in science centres, explains the methods undertaken to obtain data, the results, analysis and conclusions drawn from this research.

Chapter 2: REVIEW OF LITERATURE

2.1 Introduction

This chapter looks at some of the literature on learning and various aspects of learning within science centres. The educative role of science centres, some influences on the learning process and how the content of certain exhibits can affect learning is explored. In this paper, science centres are classified as informal or free-choice learning environments — as defined by the premise that any learning undertaken within science centres is not part of a formal education curriculum — therefore, visitors can choose to participate in and/or learn from their visit to a science centre.

There is large collection of literature that explores learning in science centres. That is, learning by individuals, family groups and school groups. The research shows innumerable observations, interviews, questionnaires and other forms of data collection that have been performed in order to gain some insight into what and how people learn in these informal settings. In the last decade or so, the research has covered topics that include measuring learning outcomes; focusing on the processes of learning and the influences on them; analysing exhibits, their contents and responses to them, and analysis of the existing research and theory development from emerging patterns.

Different papers present different perspectives on the learning experience. However, they all aspire to the same goal – to gain a better understanding of what is learned and the nature of learning in a science centre. Some of the perspectives researched have been aspects of motivation for visiting a science centre; the tasks or activities involved during the visit; the experience and learning process while there, and how this fits in with an individual's overall learning about science.

Following is a review of some research relevant to this analysis of the DSIS programs.

2.2 Educative role of science centres

Historically, science centres were largely venues to behold the 'wonders' of science by viewing objects in glass cabinets. Students would often visit on a school excursion in which they would predominantly just observe these objects; perhaps being required to answer questions on a worksheet or draw images. Generally, visits were passive, without interaction with displays, and with minimum interactivity with other aspects of the centre, such as staff. However, a new generation of science centres has emerged (Janousek, 2000; Koster, 1999) that represents a paradigm shift from the traditional to an emphasis on involvement, activity and ideas (Beetlestone *et al.*, 1998; Farmelo, 1997; Wellington, 1998, in Pedretti, 2006).

In the words of Frank Oppenheimer in 1968 – founder of The Exploratorium science centre in San Francisco – "there is an increasing need to develop public understanding of science and technology. Remarkably few individuals are familiar with the details of the industrial processes involved in their food, their medicine, their entertainment or their clothing" (Oppenheimer, 1968, p.206). Oppenheimer believed the purpose of a science museum and exploration centre would be to satisfy the growing need for an environment in which people can become familiar with the details of science and technology. Also, that it could be valuable and entertaining for the general public and would serve as a resource for schools and existing adult education programs (Oppenheimer, 1968). Based on this philosophy, Oppenheimer founded The Exploratorium in 1969, one of the first science centres in which visitors could interact with exhibits. He also created 'Explainer Programs' (Delacote, 1998) to enhance visitor, or learner, understanding of displays, that involved staff or docents who try to communicate information about the exhibits and the associated science.

These Explainer Programs focused on the learner. Goéry Delacote, executive director of The Exploratorium from 1991 to 2005, explained that they offer an active experience rather than a passive one, with the aim of fostering a sense of wonder and an ability to generate questions (Delacote, 1998). It was believed that a truly effective learning institution will engage its visitors in a dialogue, an exchange of ideas in which the exhibits and explanations engender questions, and the visitors in turn generate questions from the institute (Delacote, 1998).

Nearly forty years later, science centres are still designed to allow public access to, and information about, their particular area of science, and many conduct education programs. Most of these science centres display or disseminate scientific information to their visitors, with the aim of exposing, informing, teaching or encouraging awareness of this information. The CSIRO Discovery centre is one such place that offers publicly accessible science information and education programs for school-age students.

These informal or free-choice learning environments allow visitors to choose whether or not to engage in the information provided. That is, it is a more self-directed style of learning, without a set curriculum that progresses from lower to higher levels; that usually does not require attendance or participation, and does not certify mastery of specific knowledge at the conclusion of the visit (Hein, 2000).

2.3 Learning in science centres

Recent research suggests that nearly half of the public's science understanding and learning derives from free-choice learning environments (Falk, 2002). In a survey conducted by Falk, the largest number of respondents claimed to have learned their science and/or technology during their leisure time, through some kind of free-choice learning experience – via the internet, reading magazines or books, going to science centres or participating in special-interest groups. This and other studies (Dierking *et al*, 2004; Falk, 2004; Falk & Storksdieck, 2005), demonstrate the important role that free-choice or informal settings play in learning about science.

All learning is a continuous process. We learn throughout our lives and many factors, both internal and external, affect that process of learning. Learning requires time for reflection; that process which enables us to link new ideas and information with old, to weigh and consider, to deconstruct and reconstruct our mental models in order to assimilate and integrate our experiences into new ways of understanding, thinking and acting (Rennie & Johnston, 2004).

A visit to, and participation in, a science centre education program is just one possible learning episode in the many learning experiences we may encounter. As noted by Hein (2000), the brief encounters at science centres do appear to lead to learning, do result in change that is often remembered with pleasure and can influence future behaviour. These learning experiences, however, are bound by certain influences in the context of the event.

Looking at the nature of learning and factors that might affect it is therefore of assistance in assessing any outcomes.

2.4 Learning styles, models and theories

There is significant research that indicates people learn in a variety of ways, acquiring new information in particular ways. We develop patterns over a period of time, with which we feel comfortable, whether they are effective or not, and, although not necessarily performed exactly the same way each time, there is a set of behaviours common to each learning episode. This is what is called a learning style, and there are a number of widely used theories and models describing and evaluating the way in which we learn. For example, the Constructivist Theory of Learning; Kolb's Model of Learning; Gregorc's Style Delineation Model; Dunn & Dunn's Model of Learning; Witkin's Field-dependence/Field-Independence Theory, and Kagan's Impulsivity-Reflexivity Model (Cassidy, 2004), are just a few; there are many others.

These models define learning styles by a range of characteristics, thinking and behavioural patterns. These include verbal, linguistic, visual, spatial, auditory, musical, logical, bodily, tactile, reasoning, analytical, inductive and deductive patterns. For example, Kolb & Fry's model proposes there are four elements (experiencing, thinking, doing and reflecting) to a learning cycle, in which a learner can begin at any of these stages, but will generally show a preference for one or some over the others (Smith, 2001). Gregorc's Model also describes four distinct and observable behaviours associated with learning that includes sensory-based, intuitive, analytic, logical and verbal approaches to learning (Cassidy, 2004). Similarly, other learning theories and models incorporate various senses and behavioural patterns observed during a learning episode. Dunn & Dunn's model incorporates responses to environmental, emotional, sociological, physical and psychological stimuli (Cassidy, 2004). All of these models define how a learner perceives the world and their preferred method of working. Most learners tend to have a combination of the different styles, and do not solely use one style.

These differing styles will directly affect a person's ability to learn new information. Therefore, it is wise to design education programs to cater for the different learning styles among participants. Education programs will result in varied learning outcomes, dependent on the learning styles of the audience, thus this should be a consideration in the design, format and structure of an education program for optimal learning outcomes.

Participants in the DSIS programs at Discovery come from all over Australia and range in age from lower primary school to upper high school. Therefore, learning levels, capabilities and styles are many and varied amongst visiting school groups, which the DSIS programs are designed to consider and attempt to accommodate. All learning, however, is based upon and affected by myriad factors within an individual's life, such as what an individual already knows, how they perceive the world around them, and their personal, social and physical environments.

The Constructivist Theory of Learning suggests that learners construct their knowledge based upon prior knowledge and experience (Bruner, 1960). As described by Piaget (a Swiss psychologist and pioneer of Constructivist Theory), this happens through a process of accommodation and assimilation – as a new experience occurs, it is assessed and aligned with what an individual already knows, and if accepted, it is taken onboard as new information (Piaget, 1950).

Based on the Constructivist Theory of Learning, and taking into consideration the multitude of other possible factors affecting the process of an individual's learning, is a more recent model – the Contextual Model of Learning put forward by leading informal education specialists and researchers John Falk and Lynn Dierking in 2000.

2.5 The Contextual Model of Learning

Falk and Dierking's theory was devised by drawing from constructivist, cognitive and socio-cultural theories in which the authors state that their theory is a device for organising the complexities of learning within free-choice settings. It is described as non-predictive and proposes that learning is a complex phenomenon situated within a series of contexts (Falk & Storksdieck, 2005).

The basis of the Contextual Model of Learning is that there exists a continuous dialogue between an individual and their physical and socio-cultural environment. This contextually-driven dialogue is the process/product of the interactions between an individual's personal, socio-cultural and physical contexts over time (Falk & Storksdieck, 2005). These three contexts are not stable or constant, but change across a lifetime.

These three contexts are considered fundamental for learning in an informal setting (Falk & Storksdieck, 2005). The personal context involves the motivation and expectations of an individual, their prior knowledge, interests and beliefs, and, their choice and control over the situation. The socio-cultural involves within-group social interaction and mediation, facilitated mediation by others, and the cultural background of individuals. The physical context involves advance organisation, orientation and the architecture and design of the environment (Falk & Storskieck, 2005).

Applying this model to learning episodes within a science centre, it is clear that the three contexts of this model will affect that experience. The personal context represents an individual's personal history, along with the motivations of that individual to visit a science centre. Students participating in the DSIS programs at

Discovery are not motivated to visit by personal interest, as they are there visiting as a school-related activity. However, there may be personal interest in science that may motivate an individual student to be more receptive to the overall experience. As well as possible personal motivation, the other factors of personal context described by Falk & Storksdiek (2005) — individual expectations, prior knowledge, interests and beliefs, and choice and control over the situation — will affect the process of the learning experience.

The socio-cultural context of the students participating in the Discovery education program learning experience is a pertinent factor in this research. Visiting students participate in these programs in groups, therefore the social interactions have a strong influence on the learning experience. Considerable research now exists which shows that visitors to science centres are strongly influenced by the interactions and collaborations they have with individuals within their own social group (Falk and Storksdieck, 2005). Research has also shown that the quality of interactions with others outside the visitor's own social group, such as science centre staff – explainers, guides, demonstrators – can make a profound difference to visitor learning (Crowley & Callanan, 1998; Wolins *et al.* 1992; Koran *et al.* 1988). The DSIS programs are entirely supervised by Discovery staff – explainers and demonstrators – who have the ability to positively affect each student's learning outcome.

There is no right or wrong way to learn things, no single place or moment, we learn from many different sources in many different ways (Medrich, 1991; Anderson, 1999; Bransford *et al*, 1999). All learning is situated within the unique personal, socio-cultural and physical context in which it occurs (Falk and Dierking, 1992; 2000). That is, what people learn depends on what they already know and understand, whom they are with when they learn, where they are when they learn, and what is motivating them to learn.

The outcomes of student learning in the DSIS programs will be affected by these contexts described by Falk and Dierking. Visiting students arrive with a range of prior knowledge about science and many influences that will affect their learning experience in the education programs – for example, the informal setting, peer group interaction and personal ethics. These are factors that need consideration when assessing the learning outcomes of such programs.

Deeper exploration of these factors and how they affect learning within the DSIS programs would be of benefit to this paper, however, is beyond the scope of this research. Therefore, future studies, following-on and including this exploration, would greatly assist the understanding of the contribution each of these contexts makes to the learning process within informal settings.

2.6 The learning experience within Discovery

Theoretically, the total number of factors that directly and indirectly influence learning in a science centre number in the hundreds, if not thousands (Falk, 2004). Some of these are apparent and considered important, others less so. The most apparent variables influencing learning in the case of the DSIS programs at Discovery are prior knowledge, personal interest and motivation, peer group interaction, group size, gender, age, time of day and other activities included on the school's excursion itinerary (as most of the students are inter-state visitors with busy daily itineraries).

It has been shown that visitor learning within a science centre is strongly influenced by how successfully an individual can orient him/herself in that physical space (Evans, 1995; Kubota & Olstad, 1991). Confident navigation within a complex setting highly correlates with what and how much an individual learns. As the students participating in the programs at Discovery are guided by staff members for the 90 minute duration of the program, it is likely that this is a positive influence on the learning process.

Although Discovery's DSIS programs are not 'free-choice' settings as such – the programs are supervised by staff and guided through a set structure – the students are still able to choose whether to participate in the learning activities. They are not bound by any educational curriculum, obligation to participate or a required examination of learned material. Some segments of the program are completely free-choice activities, such as mini-lab experiments and 'additional activities' at the end of the program, during which students choose which activity they wish to perform or participate in, if at all. Therefore, these programs can be defined as informal learning environments and the Contextual Model of Learning usefully and aptly describes some of the factors affecting learning outcomes with the DSIS education programs.

2.7 The nature of learning and assessing outcomes in informal settings

During the 1980s and early 1990s researchers had started to look at aspects of affective learning outcomes, such as studies by Koran & Koran (1983) and Boyd (1993). Koran & Koran state that attitude and curiosity are critical to learning, while Boyd states that motivation and engagement are the basis to effective educational experiences. Falk & Dierking (1992) suggested evidence that student's strongest memories of a learning experience in an informal setting related to emotional aspects of the visit, although these may not relate to the content. They also investigated the contexts in which this learning takes place.

Falk & Dierking formulated their Contextual Model of Learning in 2000. As noted earlier, this model proposes three fundamental contexts for learning in an informal setting. One of those contexts – the socio-cultural – addresses group interactions. Typically with any group learning experience, the socio-cultural perspective has a particularly strong influence. As noted by Griffin (2004), with increased interest in how learning occurs within a group setting, there has been increased emphasis on incorporating a socio-cultural perspective on learning and an increased emphasis on students' learning processes, and how these can be facilitated, by paying attention to the students' views of their learning experiences.

The DSIS education programs at Discovery are designed specifically to be group learning experiences, encouraging students to ask questions and discuss topics presented to them. Discussions are generated between students and staff, but it is also desirable that the students discuss any information to which they are exposed amongst themselves. Within-group discussions were regularly observed by the author during the education programs. This could suggest that these group interactions may enhance the learning outcomes of the education programs.

Additionally, there is a body of research that supports the evidence that, although learning about science does occur during these short episodes at science centres, reinforcing this learning with pre-visit preparation and post-visit activity/information consolidates and enhances that learning experience.

2.8 Enhancing the informal learning experience with pre-visit preparation and post-visit activities

Effective learning from a science centre visit is not an isolated experience. Research indicates that previous knowledge, pre-visit preparation and post-visit activity greatly enhances the learning outcomes of a visit to a science centre. A study by Gennaro in 1981 found that students who have done work on a topic at school before visiting a science centre, and who have prepared for their visit, learn most from their experience. With some pre-visit preparation and orientation, students were less likely to concentrate on non-relevant aspects of the surroundings, and more likely to focus on those relevant to the learning intended. Research by Price and Hein (1991) concluded that promotion of long-term learning was achieved if the programs included planning; consideration of the unique opportunities of the science centre; variation in activities during the visit; sparse use of worksheets, and emphasis on first-hand experience and observation.

In a study by Anderson (1994), the effect of perceived novelty (of the unfamiliar setting) on cognitive learning at an interactive science centre was reported. The results found that students (a group of 75 randomly selected from Year 8) who underwent novelty-reducing, pre-orientation to the physical environment and had previously visited, derived and retained more information than any of their counterparts. Similarly, a study by Kubota and Olstad (1991), examined the relationship between novelty, exploratory behaviour and learning in a group of sixth grade school students.

Of the 64 students, one group was shown a slide show of the exhibit they were to visit; it included questions they might ask. The other group was shown slides from a different exhibit. As hypothesised, the second group, who were shown slides from a different exhibit, had lower scores on the post-test and reduced exploratory behaviour was observed.

The researchers also found that the novelty-reducing preparation increased exploratory behaviour and cognitive learning for boys, not in girls. Although this particular finding is not of significance for this paper, it may be of use to, or relevant for, further studies that may include learning differences between boys and girls and how this affects their learning in informal settings.

Further, Anderson's study revealed the relationships between students' responses on a post-test instrument, the students' ability to recall exhibits, exhibit content/familiarity, and whether students deemed exhibits to be interesting and/or puzzling. Among the relationships revealed, of most significance was the fact that students learned most from exhibits that they later deemed to be both interesting and puzzling (Anderson, 1994).

In another study by Anderson *et al* (1999), there was evidence that an integrated series of post-visit activities, for a group of 28 Year 7 students, resulted in their construction and reconstruction of personal knowledge about science concepts and principles represented in the science centre exhibits. Sometimes this construction and reconstruction was towards the accepted scientific understanding and sometimes in different and surprising ways (Anderson *et al*, 1999). These post-visit activities or follow-ups after a science centre visit help reveal learning outcomes from these informal learning experiences more clearly. They support the development of scientific concepts, but also detect and respond to alternative conceptions that may be produced or strengthened in an informal learning setting (Anderson, 1999).

According to research by Rennie (1994), pieces of knowledge gained from the visit experience can be consolidated during later instruction, provided the learner is receptive and able to recall these experiences. Hence, if learners consider their science centre experience enjoyable, it is likely they will be receptive to, and engage in, post-visit activity and related-learning. It has been argued that to affect learning in the visit experience, priming the learner for the subsequent instruction is also important (Rennie, 1994).

In light of this, it can be confidently asserted that if students enjoy their experience during the DSIS programs at Discovery, it is more likely that they will learn during their visit. In addition, it is likely that an enjoyable learning experience will pre-dispose students to further learning of related information, and consolidate or confirm any information to which they were exposed during the science centre experience.

However, post-visit activity may also reveal unintended learning outcomes. These may be ideas, information or alternative conceptions of science that students have formed as a result of a science centre visit. One example of this can be seen in the research by Anderson *et al.* (1999), a case study in which knowledge construction about electricity and magnetism by Year 7 students was investigated. The responses of two particular students were investigated in detail. The intended learning outcome of one exhibit was to demonstrate the effect of heat on magnetism (ie. if metal with a magnet attached to it is heated, the magnet will lose its magnetic properties and fall off). One of the students interviewed after interaction with the exhibit constructed the belief that heat has a repelling force on magnets. This of course was not the intended learning outcome of this particular exhibit.

In the case of the DSIS programs at Discovery, this may occur in response to the research topics raised and discussed during the presentations. For example, the research topic discussing dryland salinity and revegetation of farming land was intended to inform students of the problem of salinity, erosion and the resulting low productivity occurring on farms, and the benefit of revegetation to prevent further degradation. Some students, however, interpreted this situation as being beneficial to farmers, who could now sell the salt instead of their previous animal or crop produce. This understanding does have some merit, in that some of the excess of salt can actually be sold, but it is not a sustainable, broad-scale solution for this problem. The aim was to impart information about environmental degradation and agricultural disadvantage, the problems caused by these issues and the solutions provided by the research. Some of these unintended outcomes may be discussed at the time of the presentation or upon completion of the education program, however, post-visit activities and discussions may reinforce the intended outcome rather than others.

Although there may be unintended outcomes of learning situations in science centres, the results of this study indicate that most students do grasp a good understanding of the science information presented to them. This type of learning experience – one that discusses science and its relevance in day-to-day life – promotes understanding *about* science, rather than one particular scientific fact or concept. This, according to recent research by Dr Erminia Pedretti, assistant professor at the University of Toronto, leads to more robust views of science (Pedretti, 2004). Pedretti states that issues-based exhibitions – ones that present information on contemporary science and technology issues – carry the potential to enhance learning by personalising the subject matter, evoking emotion, stimulating dialogue and debate, and promoting reflexivity.

2.9 Issues-based exhibitions in science centres

As Pedretti's research findings suggest, presenting contemporary science and technology issues have a greater potential to promote learning about science. Similarly, the DSIS programs present current research in science and technology, performed by the CSIRO, some issues related to its practice as well as some possible effects on individuals and greater society — as the program name suggests.

"Teaching science is about making connections to our everyday life and relating science to larger social-cultural issues such as cloning, reproductive technologies, genetically altered food, environmental concerns etc.", (Pedretti, 2000 online).

Pedretti's comment reiterates what Aikenhead (1994), Bybee (1991) and Waks (1992), have previously stated about science education – that it should include historical, philosophical, cultural, sociological, political and ethical perspectives. Science cannot be divorced from its social purposes and responsibilities; to do so is to err on the side of presenting science as a value-free, abstract, and objective pursuit (Pedretti, 1997). Rather, science should be portrayed as a human activity, acknowledging its strengths, and its limitations.

Pedretti has conducted a number of studies (Pedretti, 1999; 2004; Pedretti & Forbes, 2000; Pedretti *et al*, 2001) exploring scientific knowledge and social responsibility and how this is taught in schools and science centres. In one paper, Pedretti (2004) looks at two Canadian science centres with issues-based exhibitions – one at Science World in Vancouver, the other installed in the Ontario Science Centre – that demonstrate the difficulty in separating science and society. Pedretti describes this type of exhibit as critical issues-based installations[5] and findings suggest that these installations challenge visitors in different ways – intellectually and emotionally.

The exhibits are titled 'Mine Games' (Vancouver) and 'A Question of Truth' (Ontario) and are designed to ask questions of the visitor about topical or controversial issues. 'Mine Games' is an exhibition that explores the impacts of building a potential mine in an imaginary town. Students use three-dimensional simulation to meet town residents, who each have their own perspective and opinions regarding the development of the mine. They are then faced with the challenge of deciding whether to, and if so, how to build the mine taking into consideration safety, economical and environmental aspects. After this task, students then engage in a discussion, guided by a mediator, in an attempt to reach consensus.

'A Question of Truth' is designed to examine a number of questions about the nature of science, how ideas are formed and how cultural and political conditions affect the actions of individual scientists. There are three topics covered in this exhibit:

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[5] By 'critical' Pedretti means exhibits that explore the nature of science and the relationship among science, technology, society and the environment.

1) Frames of reference - illustrating that differences in context can lead to many valid perspectives (eg. Sun-centred versus Earth-centred planetary models, western medicine and alternative views on health and well-being),
2) Bias in science and society – examines the long history of oppression and marginalisation for certain groups of people (eg. concepts of racism, prejudice, eugenics, slavery, sterilisation, intelligence testing), and
3) Science and the community – suggests our future depends on an informed and active citizenry, and includes interviews with scientists, contributions from local school children and street kids and visitor reactions to it.

Such exhibitions evoke many responses and have also created controversy, because it is questioning the pursuit of science (Pedretti, 2004). They invite visitors to consider socio-scientific material from a variety of perspectives, engage in decision-making and healthy debate of complex issues, and critique the nature and practice of science and technology. These exhibits emphasise learning *about* science, developing an understanding of the nature and methods of science, an appreciation of its history and development, and an awareness of the complex interactions among science, technology, society and environment (Pedretti, 2004).

The DSIS education programs at Discovery aim to communicate information about scientific research and issues related to performing that research. The programs encourage visiting students to think about a number of issues related to performing this research – such as practicalities (how will it be performed), social and societal impacts (how will it affect individuals and society), economic decisions (how much will it cost and who pays for it), desired outcome (what is the main purpose of the research) and beneficiaries (who or what benefits the most from it). As with Pedretti's study, raising questions and encouraging discussion of issues related to carrying out the research has been seen to enhance learning about science. Additionally, research by Paris *et al.* (1998 p.280, in Griffin, 2004), states that "interest in a topic involves both feeling-related characteristics, such as enjoyment and involvement, and value-related characteristics, such as attributing significance to an activity". The DSIS programs include both these aspects.

Science centres are beginning to see themselves as important players in a number of external scientific, social, cultural and political contexts (Beetlestone *et al.*, 1998). Today's mass media allows information about science to enter most people's daily lives, so many science centres have evolved to represent popular, topical or controversial issues, realising not only their educative role about science, but their role within society.

2.10 Summary

The literature presented in this chapter showed the change in the role of science centres from places to observe objects to places where interaction with exhibits is now popular. Science centres can provide a significant role in informal education to both individual visitors and school groups, and a number of studies explored the nature of these learning experiences. Many theories and models of learning have evolved in the past 50 years that have informed the understanding of learning in science centres. Further research into the processes of learning in such environments has seen the formulation of theories specific to informal learning. Other studies investigated the type of exhibits within a science centre and demonstrated how these can affect the outcome of a learning experience and overall perceptions of science.

The following chapter outlines the methods used for assessing the learning outcomes of the DSIS education programs being studied in this paper.

Chapter 3: RESEARCH METHOD

3.1 Introduction

This chapter describes the methods used in this research. It explains the way in which data were collected using survey questionnaires that were sent to participating student groups, via their teachers. The survey also contained several questions directed at the teachers of each group. Also outlined is the use of quantitative research methods for this research, reasons for this course of action for acquiring data, the rationale behind choices of survey questions and the limitations experienced using this method.

3.2 Survey Research Methodology

3.2.1 Quantitative research

Quantitative methods were used to analyse the survey data in this research. This method enabled evaluation of the learning outcomes of the science education programs. Survey research is a commonly used quantitative method for obtaining data through sampling a population. Defined by Babbie (1999), quantitative analysis is the technique by which researchers convert data to numerical form and subject it to statistical analysis. In survey research, the researcher selects a sample group from a population and administers a questionnaire to that group.

3.2.2 Sampling

The goal of most surveys is to enable the researcher to accurately describe or predict the characteristics or thoughts of a pre-defined group of people (Doyle, 2004). Surveys enable data to be collected from large or small populations, from the entire population or via sample groups. In a review of quantitative research design conducted by Yu and Cooper, it is noted that Williams states that the use of sample groups to obtain relatively precise information about a population is a very efficient technique (Williams, 1978, in Yu & Cooper, 1983). It enables the researcher to make inferences about the population at much less expense as a complete census. Also, the sample may prove to be more accurate than a census, because the latter has greater potential for non-sampling error[6] (Williams, 1978, in Yu & Cooper, Statistics Canada, 2006 online). That is, previous research has been found that the likelihood of non-response and errors due to sampling technique is greater in census surveys than sample surveys.

3.2.3 Errors

In research by Assael & Keon (1982), non-sampling error is the major contributor to total survey error, while random sampling error is minimal. Random sampling error can be controlled by careful selection of the sample and increasing the sample size (Assael & Keon, 1983).

Also, low return rates can result in insufficient data and errors in analysis and interpretation. It is suggested in research by Yu & Harrison (1983) that preliminary notification and follow-up are relevant and valid techniques that may increase return rate.

3.2.4 Questionnaire Design

It is important to construct a valid and reliable questionnaire. It needs to be understandable and easy to follow for the intended respondents. If respondents feel a survey is important and easy to complete, they are more likely to complete it (Doyle, 2004). If it looks complicated and difficult, they are less likely to participate, therefore resulting in low return rates.

A survey questionnaire may be created in various forms – a written document (usually for mailing), on-line questionnaire, face-to-face interview, telephone interview or focus group. Mail surveys should contain accompanying information, such as a cover

[6] Non-sampling error refers to errors arising during the course of all survey activities other than sampling. These may include non-responses from survey participants and errors not related to the responses, such as computer malfunction, researcher miscalculation or reporting errors.

letter explaining who is conducting the research and why, a brief description of the survey content and issues regarding legalities, confidentiality and privacy.

The organisation and format of the question sequence should be considered carefully to guide the respondent through the survey with ease and without error. A questionnaire could contain a number of question types, requiring a variety of answers; for example, numerical or written answers. Questions may be closed-ended questions (selecting from specified options) or open-ended responses allowing explanation. The questionnaire should be standardised to ensure reliability, generalisability and validity, with each respondent being presented exactly the same questionnaire (Doyle, 2004).

3.2.5 Ethical Considerations

All researchers have an ethical obligation to protect the welfare of the people they study. Respondents should be informed that participation is voluntary, that they may omit answers to any particular questions if they choose or they can refuse to participate altogether.

Research involving school students can be ethically sensitive. The safety and welfare of students must be protected at all times. Survey content and data collection techniques are dependent on associated ethical issues and protocols. Approval is required from ethics committees and/or parents, school staff and education authorities[7].

3.2.6 Data analysis

Quantitative research uses various forms of analysis. This research uses univariate analysis, a simple form of quantitative analysis. Babbie (1999) defines this analysis as describing a case in terms of a single variable – specifically, the distribution of attributes that comprise it. Univariate analysis is first and foremost the assessment of the distributional properties of a variable. It serves two broad purposes: (1)

[7] This research was approved by the Human Ethics Office of the Australian National University and the principal of each participating school.

description and (2) preparation for multivariate analysis (Aneshensal, 2004). This involves presenting univariate data by reporting on individual cases by listing the attribute for each case under study in terms of the variable in question (Babbie, 1999). Univariate analyses allow descriptive inferences to be made about the larger population, if the sample is appropriately drawn from that population.

Data may be calculated in terms of frequency distribution of a unit or value. The frequency count condenses the information contained within the data (Aneshensal, 2004). The frequency distribution data can then be condensed further by calculating measures of central tendency – values that summarise the characteristics or qualities of a set of values as to be fully representative of the set (Aneshensal, 2004). The central tendency summarises the distribution set into a single average quantity or quality, measured using the mode, median or mean[8].

3.2.7 Advantages of surveys

Conducting research via surveys has many advantages. Most of the literature concludes that survey data collection techniques are an inexpensive and efficient way of collecting information from a large number of respondents. These large sample sizes often result in significant information.

Marshall and Rossman (1995) state that the strengths of survey data collection methods include accuracy, generalisability and convenience. Accuracy in measurement is enhanced by quantification and replicability. Survey results can be generalised to a larger population within known limits of error. Also, surveys are amenable to rapid statistical analysis (Marshall & Rossman, 1995).

Another advantage of surveys is that they can access respondents in distant and remote areas, therefore including a greater number and variety of respondents in the sample, enhancing the accuracy and representation of the total population.

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[8] The *mode* of is the most frequent value of the set; the *median* is the middle value of the set and the *mean* is the average value of the set.

Over 50 years ago, Angus and Katona (1953, in Colorado State University, 2006, online), stated "It is the capacity for wide application and broad coverage which gives the survey technique its great usefulness." This view still applies today. However, surveys do also have their limitations.

3.2.8 Limitations

Using surveys for data collection can have weaknesses. They depend on subjects' motivation, honesty, memory, and ability to respond. Of a sample group, some may respond while others do not, therefore, non-response errors may bias the result. Measurement errors may also occur when respondents answer questions inaccurately. This may be due to question wording, question ordering or other external factors (Western Michigan University, 2003, online). Answers may lead to vague data sets as the respondents' answers may be interpreted differently to their meaning by the researcher.

Another weakness of surveys is that they may have little value for examining complex social relationships, intricate patterns of interaction or represent the broader universe without further investigation (Marshall & Rossman, 1995). This research however, is not examining detailed relationships or interactions, nor a broad-scale universal group. It is exploring individual group responses of students from a sample group (20 school groups who participated in the DSIS education program) that represents a larger group (all student groups who participated in the DSIS education programs within the surveyed timeframe), but not universal population (all student groups who have visited Discovery).

One other limitation of survey research is seen in return rates. Generally, a higher response rate of a survey will provide more valid results, and this of course is what any researcher strives for when using survey methods. Higher response rates are needed when the assessment's purpose is to measure effects or make generalisations to a larger population. However, high response rates are less important when the purpose is to gain insight (Educational Benchmark, 2005).

There has been considerable debate during the past few decades over a definition for response rate estimation standards (Johnson & Owens, 2003). Although there has been some definition set, it is still debated because some believe response rate to be only one indicator of a survey's ability to be representative of the sample.

According to Yu & Harris (1983) return rates for surveys can be increased by preliminary notification, foot-in-the-door techniques, personalisation and follow-up letters. If these techniques are not employed, return rates may be low.

3.3 Research Method

3.3.1 Data collection rationale

The survey questions in this research were designed to answer the research questions and therefore explore the research problem being investigated.

A survey questionnaire was the preferred method as it provided a small amount of information about a large number of subjects. As stated by Marshall and Rossman (1995), the basic aim of survey research is to describe and explain statistically the variability of certain features of a population. The aim of this questionnaire was to identify some of the likely variables in learning outcomes from these particular education programs, and possibly reveal others.

This survey examined many small sample groups from the larger population of students participating in the DSIS program. It gathered information on beliefs and attitudes of the sample groups of students; an appropriate mode of making inferences about the larger group. Targeting small groups, within the larger population, provided better collection, management and analysis of data, therefore being likely to enhance the success of obtaining accurate, useful and relevant results about their learning experiences. Thus, this method best suited the ability to satisfy the research questions posed, and explore the research problem.

3.3.2 Sampling

The sample group was selected from a list of school groups that visited Discovery between February and June 2005, who participated in the education programs that were conducted during the day. School groups also visit during the evening, but were excluded from the sample group as they vary slightly from the day group program.

This four-month timeframe was chosen because all groups were exposed to the same education program and research talks during that time. There was a variation in the research topic for one group, and another group did not participate in a voting activity, but this was not known at the time of sample selection. These minor variations, however, did not affect the analysis in any significant way and therefore were included in the sample group.

Fifty-three school groups were selected from the list of those who participated in the daytime 90-minute DSIS program.

The sample group included students from both primary and secondary classes – Years 5/6 through to Year 12. The sample group included schools from the following states – NSW, VIC, QLD, SA and TAS – and one territory – ACT.

The type of schools in the sample group included both public and private schools, and co-educational and non-co-educational schools. The range of class years, school locations and types in the sample group are representative of the variety of schools that visit Discovery.

Surveys were mailed out in two batches – Round 1 and Round 2. Round 1 included school groups who visited Discovery from 16 February to 18 May 2005. Round 2 included groups who visited between 18 May and 10 June 2005. A higher number of school groups visited Discovery during May and June, than the number visiting between February and May.

Reminder letters were sent during the following two-month period (July-August) to groups from Round 1 who had not responded to the initial mailout. Time constraints did not allow for further follow-up reminder mailouts to Round 2 groups.

Once surveys were received, teachers were requested to garner data from the students in a group within a class setting. Each survey represents one class group, made up of multiple student responses. Classes varied in size, averaging approximately 20 students.

The responses to these questions were then analysed using quantitative methods to evaluate the learning outcomes of the education programs. Initial data was collated, results assessed and conclusions drawn from the findings.

Surveying school students usually entails many ethical considerations. The survey method used in this research avoided direct contact with students, thus avoiding the possible ethical issues associated with child safety and welfare.

3.3.3 Survey Design

Data were collected via survey questionnaire. The survey contained eight questions to the students of each group about their participation in the DSIS programs. Questions directed at students were chosen in order to address the research questions of this paper – do the education programs satisfy the objectives set for them; do students learn any science information; if so, what and for how long, and do they enjoy the program format. The first three questions ascertained whether students remembered the CSIRO and the research it performs. The other five questions pertained to what students did during the education programs and their level of enjoyment of these activities.

The survey also contained three questions to the teachers of each group. These questions aimed at gleaning the teachers' interpretations of their group's understanding of the science information to which they were exposed during the education programs, and observations of any possible post-visit changes in relation to science after their science centre experience.

The survey design included both closed-ended and open-ended questions. A yes/no response was requested, and reasons for their answer. These closed questions were intended to gain the students' or teacher's immediate response to the question, while the open part of the question allowed some detail for each answer.

3.3.4 Survey Questions

The questions used in the survey were chosen because they directly address the objectives of the Discovery education programs. The questions, and their rationale for inclusion, are outlined below.

QUESTIONS TO STUDENTS

Questions 1-3 – CSRIO

1) Who is CSIRO? (2) What does CSIRO do? (3) What kind of jobs do people do at CSIRO?

These questions investigate students' recall and ability to identify CSIRO and its functions. These questions address the first research question (see p.13), which investigates the first objective of the education programs – to raise awareness of CSIRO among school age children (see p. 5).

Question 4 – Activities

What do you remember doing at Discovery? Did you like doing this?

Question 5 – Program and interaction with staff

Did you like the way the staff showed you around the exhibit and talked to you?

Question 6 - Enjoyment of participatory role-play activity

Did you enjoy participating in the role-play situation and casting a vote at the end?

These questions investigate students' recall of activities performed during the education program, students' enjoyment level of the program format and participation in the role-play activity. They addressed the second research question (see p.13), which investigates the second objective of the education programs – to engage students in a scientific funding decision-making scenario (see p.5).

<u>Question 7 - Science information</u>

What do remember about science (in general) from your visit to the Discovery Centre?

This question investigates students' recall of science information after their participation in the education program. This addresses the third research question, which investigates whether students learn any science information, and if so, what type and quantity do they learn (see p. 13).

<u>Question 8 – Importance of scientific research</u>

Is it important to society to conduct scientific research? Why?

This question investigates whether students value the practice of scientific research. This question addresses the third research question (see p. 13), which investigates the third objective – to raise awareness of scientific research and its benefits (see p. 5).

QUESTIONS TO TEACHERS

<u>Question 1 – Students' level of interest in science</u>

Has your students' level of interest in science increased at all since visiting CSIRO Discovery?

<u>Question 2 – Recalling Discovery visit</u>

Do your students mention their visit to CSIRO Discovery?

<u>Question 3 – Science information learned</u>

Do you believe your students learned some scientific information, or something about science, from their visit to CSIRO Discovery? If so, what did they learn?

All three questions to teachers were designed to elicit an overview of the students' learning experience through the teachers' post-visit observations. The questions were intended to explore whether the teachers' opinions supported or reinforced the notion that students learn science information from their science centre experience, therefore contributing to answering the research questions.

The survey questionnaire was mailed to the sample group of school students who participated in the DSIS education programs at Discovery. This was done eight to ten weeks after their visit, in order to capture short to mid-term retention of information learned during their science centre visit.

3.3.5 Limitations of Method

Some limitations were experienced using survey methods for this research. Some of these included sample size; response rate; possible inaccuracies in responses, and the inability for direct contact with students.

Although the initial sample size (53 school groups) was representative of the larger population of school students who participated in the DSIS programs, only 20 groups responded. This response rate, although adequate, could have been higher. A higher return rate would have yielded more a more abundant data set, greater accuracy in the results and a more detailed comprehension of the learning outcomes of these education programs.

This return rate could have been increased with pre-survey contact, multiple reminder letters and some sort of incentive to motivate respondents to participate. This may have afforded a better data set and more comprehensive analysis. Unfortunately, time constraints prevented these particular techniques to be enacted.

Not dealing directly with each student of the school groups was a limitation in this research by not being able to directly access their exact thoughts and opinions. By surveying the students via their teacher, answers may be incomplete or inaccurate. Teachers may not have included all responses by students; modified their answers;

over-emphasised, neglected or negated some opinions, or recorded an interpretative rather than verbatim response.

One last limitation in this research was the survey questionnaire design. Extraction of the precise relevant and meaningful information about the learning outcomes could have been improved with additional or more explicit questions. If survey questionnaires are too long and complex, with too many questions, it lowers the likelihood of the recipient responding, thus limiting the success of the survey in the first place. However, if the questions are not carefully worded, the necessary information for exploring the research problem will not be elicited. The survey questionnaire used for this research would have benefited from containing another question or two, and modification to some existing questions. For example, an additional question, or modification to Question 7, may have clarified the information about scientific information learned by students during the DSIS programs, by giving more specific or detailed responses.

3.4 Summary

The method used for collecting and analysing data in this research was chosen to provide results that would address the research questions. It was an efficient means of acquiring data from the sample group, which represented the larger population of school groups participating in the DSIS programs, and provided relevant responses. Although some limitations were experienced in the return rate and non-response to a few questions, an adequate data set was obtained for analysis.

The results of this research are presented in the following chapter. From these results, conclusions have been drawn and are put forward in the final chapter of this thesis.

Chapter 4: RESULTS

4.1 Introduction

This chapter provides data in response to the research questions of this thesis:

1) Do the education programs fulfil the objectives set for them? (As stated on p.5)
2) Do participating students enjoy the activities/format of the education programs?
    a. If so, does the format have an affect on student learning?
3) Do the participating students learn any scientific information?
    a. If so, what scientific information do students learn?
    b. If learned, how long do students retain the scientific information?

Data was collected via survey questionnaires, with questions directed to both students and teachers. Surveys were sent to a sample population of 53 school groups who participated in the daytime DSIS programs between February and June 2005. Groups visiting in the evening and special groups were not included in the sample. Each school group varied in size, with an average number of 44 students per group. The sample is representative of approximately 2332 students.

Of the 53 groups in the sample, 20 (n) responded. The return rate of the sample population was 37% (20/53). Their answers are condensed into collective class responses from each of the 20 groups. The following tables and analyses show the results.

4.2 Data Analysis

In collecting data, school groups were categorised into class year; geographic location; type of school (public or private), and single or mixed gender school (co-educational/non co-educational) groups. These criteria were recorded for the possibility of identifying any patterns or trends that might occur in the data but were not essential for addressing the research questions.

The following tables show these category breakdowns.

Table 4.1: Sample group by class year, geographic location and type of school (n = 20).

Class grade (n)					
Year 5-6	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
2	7	7	1	2	1
State/Territory * (n)					
ACT	**NSW**	**VIC**	**QLD**	**SA**	**TAS**
3	5	4	6	1	1
Public (n)			**Private (n)**		
17			3		
Co-educational (n)			**Non co-educational (n)**		
18			2		

* Australian States and Territories: ACT = Australian Capital Territory; NSW = New South Wales; VIC = Victoria; QLD = Queensland; SA = South Australia; TAS = Tasmania.

Class

Results show that the majority of school groups who participated in the programs were in Years 6 and 7. Therefore their ages ranged from 11 to 13 years. The total age range of the students is approximately 9 to 16 years.

Location

Seventeen of the surveyed school groups travelled from inter-state. Three were school groups local to Canberra. Therefore, almost all school groups visited Discovery as part of an inter-state field trip, while the groups from the ACT were visiting on day trips from school.

School type

The vast majority of groups were from co-educational public schools. Only two groups were non co-educational, and only three groups were from private schools.

4.3 Survey questionnaire answers

4.3.1 STUDENT RESPONSES

Questions 1-3 – CSRIO

1) Who is CSIRO? 2) What does CSIRO do? 3) What kind of jobs do people do at CSIRO?

These questions were asked to determine students' recall about the CSIRO and what it does.

Box 1: Percentage analysis of responses to Questions 1-3

Q 1)	75% of student groups correctly recalled CSIRO's full name
Q 2)	90% of student groups correctly identified what CSIRO does
Q 3)	100% of student groups correctly recalled the roles of CSIRO employees

The results of this set of questions showed a high level of recall and retention about CSIRO. Of the 25 percent of student groups who did not recall CSIRO's full name, their answers related CSIRO to science research and science in general.

Students correctly identified that CSIRO is an organisation where scientific research is carried out (described using words such as tests, experiments etc), and that the work people perform at CSIRO is mostly scientific research, carried out by scientists. Some examples were biochemists, biologists, entomologists, dieticians, environmental researchers and engineers. Five groups mentioned other staff, such as lab assistants, administration staff and fund-raisers.

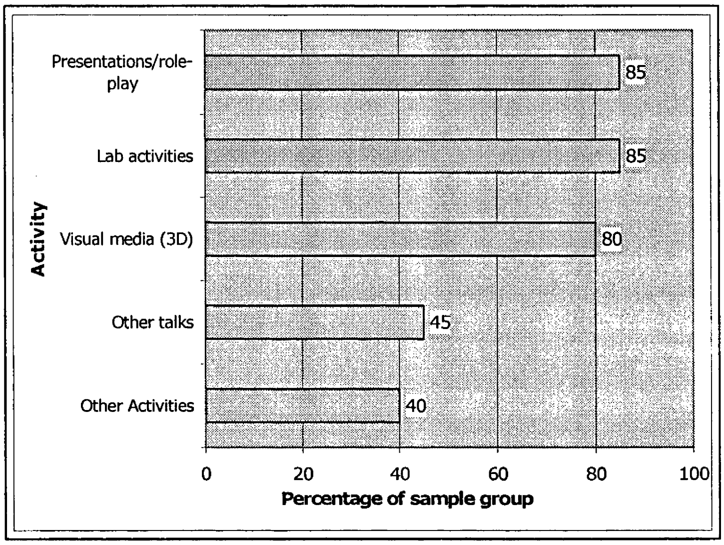
(See Appendix 2 for further detail of responses)

Question 4 – Activities

What do you remember doing at Discovery? Did you like doing this?

This question was designed to ascertain what particular parts of the education programs the students recalled, and if they enjoyed participating in these activities. This addresses research questions 1) and 2) in determining whether the program objectives are being met, and whether the students enjoy the activities and format of the program.

Chart 4.1: Percentage analysis of sample groups' recall of DSIS activities. (n=20).



Box 2: Number of Yes/No group responses to enjoyment of DSIS program activities

YES	NO
20	0

Response frequencies

Of the 20 student groups, 17 groups remembered the presentation talks; 17 groups remembered the lab activities; 16 groups recalled the visual media; 9 groups recalled the other talks, and 8 groups recalled the other activities. These were converted into a percentage of the total.

All 20 groups answered that they enjoyed these activities.

All groups stated that they enjoyed all the activities they were involved in during the DSIS programs. The most frequently recalled activities were the role-play/vote-casting scenario activity, hands-on lab experiments/activities and the 3D movie viewing.

The 'Other talks' and 'Other Activities' were part of the education programs, but secondary to the presentation/role-play and lab activities. The program format specifically focuses on the latter activities, which determine whether the program objectives are fulfilled; the results showed they were satisfied.

See Appendix 2 for detailed responses of group answers.

The results from this question showed that students recalled a lot about their science centre experience at Discovery. Most remembered all the activities as well as some other information. Of note, one group recalled nine activities/pieces of information about the education program in detail. The teacher of that group remarked, with underlining for emphasis, that she did not prompt her students at all, implying they recalled the level of detail themselves.

Question 5 – Program and interaction with staff

Did you like the way the staff showed you around the exhibit and talked to you?

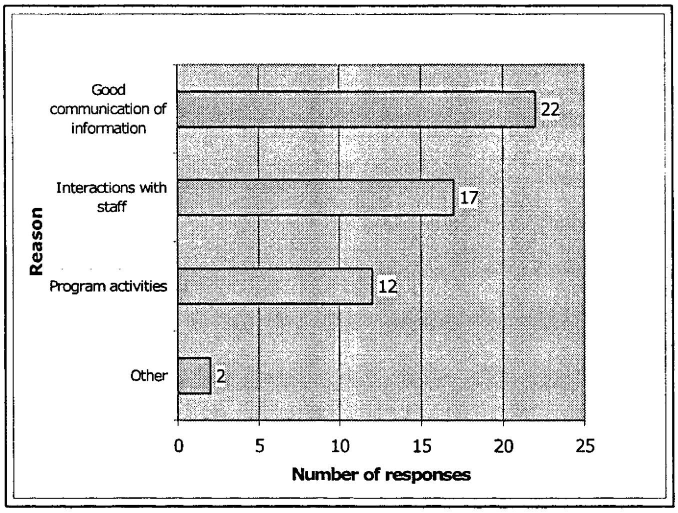
Students were asked about whether they liked the staff guidance and interaction with them. This question was aimed at answering research question 2) Do students enjoy the format of the education programs?

Box 3: Number of Yes/No responses from groups for enjoyment of staff guiding students through program (n=20, with 2 groups responding both Yes and No)

YES	NO
19	3

All but one student group answered that they liked the staff showing them around and talking to them. Students stated they enjoyed the program and format for a variety of reasons. Chart 4.2 categorises these reasons.

Chart 4.2: Frequency distribution of students' reasons for enjoyment of staff guiding students through program



The most frequent responses from student groups to this question related to their experience with staff members, as seen in the first two categories in Chart 4.2 – the way in which staff communicated scientific information, and their interactions with Discovery staff. Some comments included that staff were friendly, kind and helpful; that they listened to their opinions and answered their questions in an understandable way, and were knowledgeable and looked intelligent. As one Year 8 group sums up the communication of the scientific information:

It was explained in a "scientific manner, but not complicated."

The students clearly enjoyed and appreciated interaction with staff, while at the same time receiving science information in a way they could understand.

Twelve comments referred to the education program itself as the reason for their enjoyment. Several student groups thought the program was fun, while others commented that is was not boring; showed how things worked; was interesting and had variety. Other comments described the enjoyment of the activities – four groups mentioned they liked the hands-on lab activities most, while another enjoyed the role-play vote-casting activity best.

The two comments in the 'Other' category were more abstract comments about the program.

Three student groups responded that they did not like the program and format. The reason given by these groups was they believed there was a lack of time and the inability to see other exhibits. However, two of these groups also answered 'Yes', that they did enjoy the program. One group's reason was that staff explained the information well, and the other group's was that they loved the hands-on activities during which they "learned heaps".

(See Appendix 2 for further details of responses)

Question 6 - Enjoyment of participatory role-play activity

Did you enjoy participating in the role-play situation and casting a vote at the end?

This question explores student responses to the science research talks. The role-play scenario is the main part of the education program, and the pathway to meeting two of the program objectives – to raise awareness of scientific research and its benefits, and engaging school students in a scientific funding decision-making process. This question elicited information about the students' enjoyment level and response to this activity. Box 3 and Chart 4.3 below show the student groups' responses.

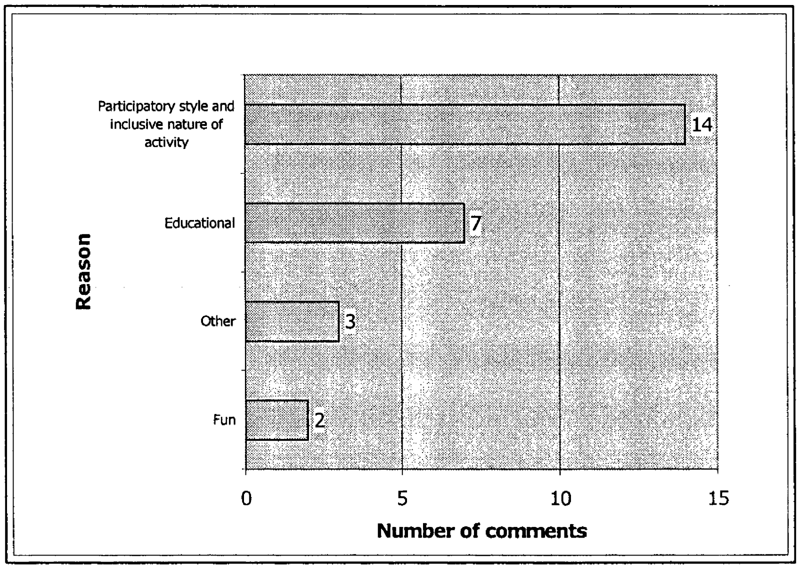
Box 4: Number of Yes/No responses for student groups' enjoyment of role-play activity (n=19)*

YES	NO
18	1

* One group heard the presentation talks but were not involved in a voting activity

All but one group of the 19 participating groups enjoyed the role-play activity and casting a vote. Their reasons are clustered in Chart 4.3 below.

Chart 4.3: Frequency distribution of student groups' reasons for enjoyment of role-play and vote casting activity



This distribution illustrates some of the clustered groups of reasons for enjoyment of this activity. The student groups' most frequent reason relates to the activity's participatory and inclusive nature. Comments included enjoying feeling involved/ included in the decision-making process; being able to express their opinions; hearing others' opinions; a feeling of importance, and their opinions being valued. The following comment from one Year 5/6 group demonstrates involvement was felt on a broader scale:

"Makes you feel like you could be part of the community"

Some comments about the participatory style of this activity included enjoying the hands-on nature of the activity; the decision-making process; being able to cast a vote, and that it was better than just listening and taking notes.

Student groups' next most frequent response related to the educational value of the activity. Group comments included that this activity was explanatory [about science research]; the research topics were real-life situations, and they helped with life by providing a greater understanding and solutions. One group pointed out they valued and enjoyed finding out more about science and research for the following reason:

"People can tell what's happening in the scientific world"

A couple of groups noted that this activity was fun, and the three reasons in the 'Other' category are listed below:

> *"Gave purpose to visit"*
> *"Felt professional"*
> *"Helps the world"*

It is clear that student groups enjoyed this role-play activity for being able to actively participate, for feeling included in the process and being able to express some thoughts about it. Results revealed that groups believed it was an educational activity – providing information about the process of scientific research and its outcomes. One group stating that the activity *"made it clear how hard some decisions are"* (Year 6/7) Only one group did not enjoy the role-play activity. Their explanation was that they believed it was not involved enough, and suggested including a debate at the end about the research topics presented during the program.

(See Appendix 2 for further details of responses)

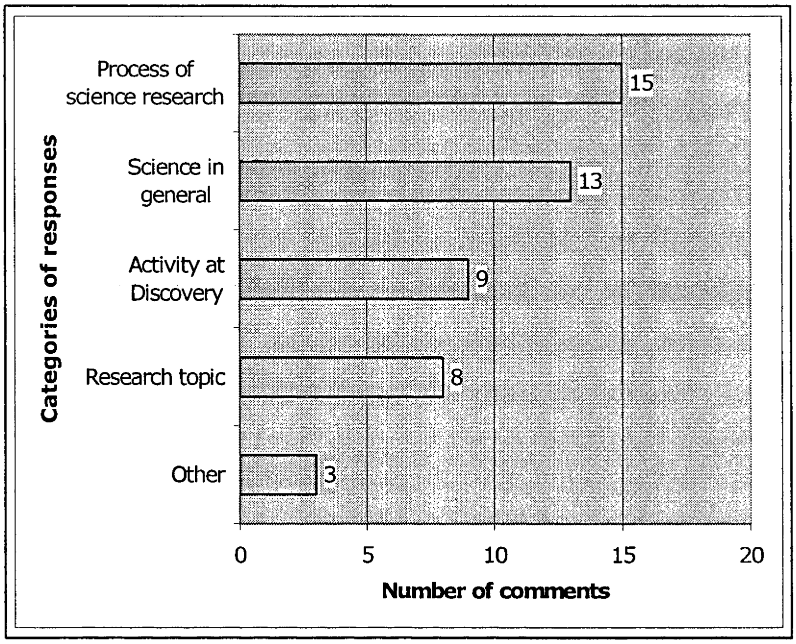
<u>Question 7 - Science information</u>

What do you remember about science (in general) from your visit to the Discovery Centre?

The aim of this question was to determine what information students retained about science from their visit to Discovery. It was an important part of satisfying research question 3) Do participating students learn any scientific information?

Students recalled a variety of information about science. Their responses are clustered in Chart 4.4 below.

Chart 4.4: Frequency distribution of clustered responses of student groups to what they remember about science



The most numerous responses by student groups were related to the process of scientific research. Some examples of comments are that science is a process; that there are a lot of procedures; that it takes time and money, and that it is hard to do.

The next most frequent responses were about science in general. Comments included that science was very important; it helps all of us; it is interesting; there are lots of different facets to it, and five comments stated that science can be fun. One group's comment was:

> Science is *"not just test tubes and science labs"*.

Many student groups recalled and described aspects of the activities that they participated in at Discovery. These responses did not answer the question posed, about their recall of science information. Of the 48 responses recorded, the 9 recalling activities did not specifically answer the question.

The next most frequent responses pertained to the current scientific research projects presented to groups, describing specific information about the project. For example, they learned about bowel cancer, microencapsulation technology and environmental issues.

The final three comments were less specific comments. These are listed below, and do not specifically relate to science information learned.

Physics
Biology
That we need to do our part to help the environment

These answers show many overall perceptions about science, the practice of scientific research and what students' learned from the education programs.

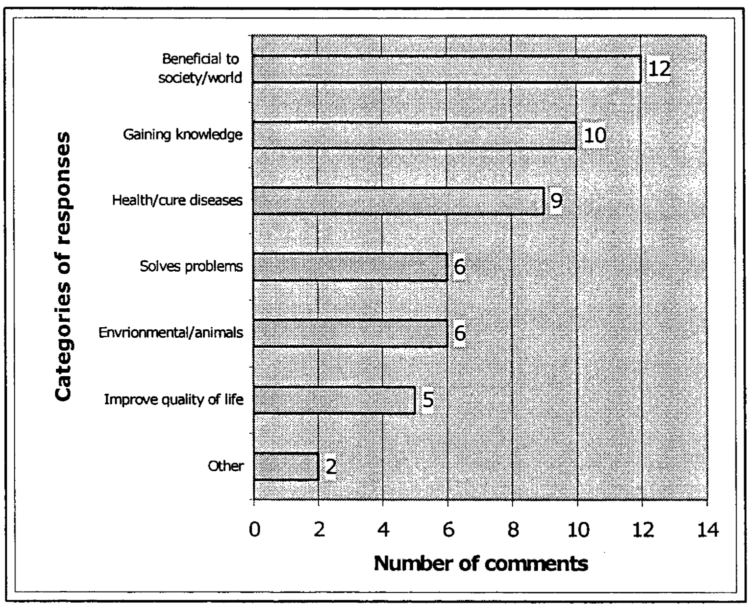
(See Appendix 2 for further details of responses)

Question 8 – Importance of scientific research

Is it important to society to conduct scientific research? Why?

This question was asked to glean the students' opinion on the value of scientific research. All student groups agreed that scientific research is important to society. Their responses are summarised in the Chart 4.5 below.

Chart 4.5: Frequency distribution of clustered responses from student groups in response to importance of scientific research



The most frequent response was that science is beneficial to society and the world. This is indicative that students predominantly believe scientific research is important because of its beneficial consequences to society and the world. Most students also saw scientific research as a process for acquiring knowledge. The results show that they see scientific research as the path to cure diseases; help the environment and animals; improve quality of life; gain a better understanding of how the world works – therefore solving problems – and evolve society and make technological advances. The following two comments are examples of the feelings expressed by a number of groups:

> *"Makes our world better"*
> *"Makes society go forward"*

Their answers reflect a strong emphasis on the benefits of scientific research, particularly for improving human life.

(See Appendix 2 for further details of responses)

4.3.2 TEACHER RESPONSES

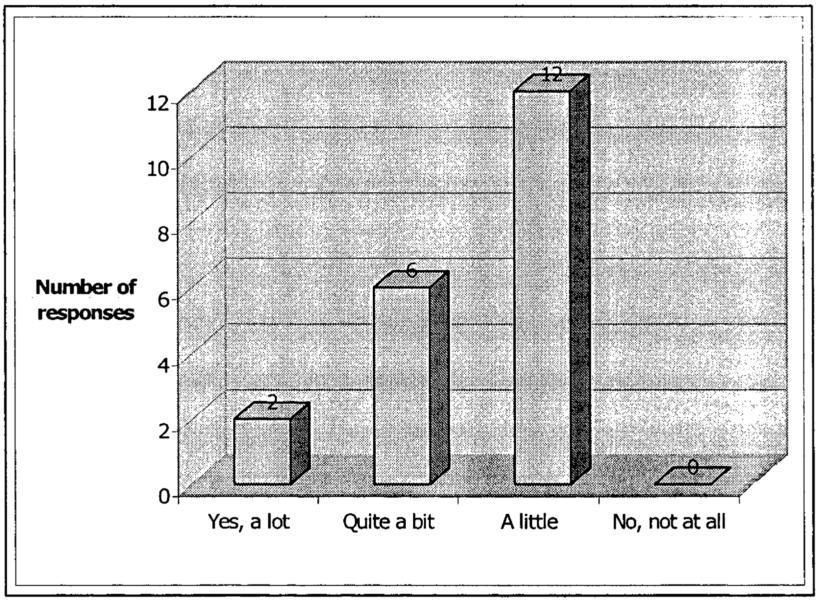
<u>Question 1 – Students' level of interest in science</u>

Has your students' level of interest in science increased at all since visiting CSIRO Discovery?

In addition to gleaning information from students, questions were posed to the teacher of each group in order to gain an overview of the students' attitude towards science, and whether this had changed in any way after their science centre experience.

Teachers were asked to give a Yes/No answer, as well as the option to add further comments. The following Chart 4.6 show their responses.

Chart 4.6: Frequency distribution of teacher responses to student groups' increased interest in science (n=20)



Teachers' responses to this question indicate that there was some increase in their students' level of interest in science. The majority of student groups reported a small increase, with only two groups showing a relatively high increase. However, none of the teachers answered 'No' that their students' level of interest in science did not increase.

Unfortunately only seven teacher comments directly answered the request of additional feedback relating to any post-visit classroom change in interest in science. These are listed below in Box 5.

Box 5: Teachers' responses to their group's increased level of interest in science

- *"More interested [in science] and sometimes refer to some things we did [at Discovery]", Year 5/6 group*
- *"In certain areas ... environment and biodiversity, endangered species, finding cures", Year 7 group*
- *"We used our visit to CSIRO to encourage students to do their own experiments", Year 7 group*
- *"The students' interest and retention of information was very high". Year 6 group*
- *"Some individual children", Year 7 group*
- *"It consolidated issues with the environment that we had discussed in class." Year 9 group*
- *"They really enjoyed it [talks about research] ... and could see the relevance of it [research].", Year 6 group*

Six teachers surveyed indicated the level of change in their group's interest in science, but gave no additional details. The remaining seven teacher responses were related to their visit to Discovery and the experience of the DSIS programs.

Error and Non-response

It would appear that there was some misinterpretation of the question posed.
The question sought possible demonstrated change in student interest in science – observed classroom activity, thoughts, actions or discussion – since participation in the DSIS program. However, the information given by seven teachers related to their time spent during the visit to Discovery, and six teachers gave no detail in their answers.

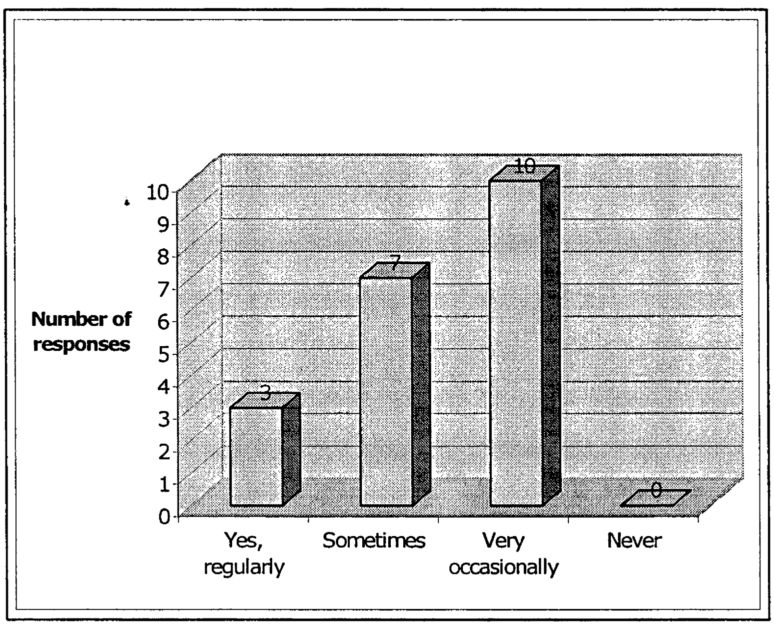
(See Appendix 2 for further details of responses)

Question 2 – Recalling Discovery visit

Do your students mention their visit to CSIRO Discovery?

This question was asked to determine whether the Discovery visit was memorable to students, over the research timeframe (2005). Teachers were asked to select a category into which their group fits, about mentioning their Discovery experience. They were then given the option to comment further.

Chart 4.7: Frequency distribution of teacher responses to student groups' recall of DSIS programs



Some student groups recall their Discovery visit regularly, but the majority of groups only recalled it some of the time or occasionally. Interestingly, no teacher responded that their students 'Never' recalled their visit.

Only 11 of the 20 groups gave further detail. Nine groups did not comment further.

Results indicate that most students recall their Discovery visit when prompted, that is, when mentioned by the teacher or if a related activity or topic arises in class. Often this was during a science-related class. One teacher noted that some individual students' recall was much greater than others. Some of the topics that students recall are listed in Box 5 below.

Box 6: Topics recalled by students after DSIS program

- Research topics – colon cancer research
- Process of research and funding – research and why it happens
- Voting activity – enjoyment of participation
- 'Other activities' – DNA extraction

When reminded about their Discovery visit, or when something triggered a memory of it, students recalled information about the science research presented during the talks, such as colon cancer. There were also comments on discussion of the voting activity, funding procedures and handling the live creatures (stick insects and mice).

One teacher quoted her Year 6 group as saying:

> *"When I hear or see anything about the CSIRO I talk about it."*

As a consequence of their visit to Discovery, some teachers noted that their students have displayed a greater awareness of and interest in the world around them.

Question 3 – Science information learned

Do you believe your students learned some scientific information, or something about science, from their visit to CSIRO Discovery? If so, what did they learn?

This question had an ancillary role for satisfying the third research questions put forward – Do students learn any scientific information? It invited teachers to give their opinion on any observed learning outcomes from their visit to Discovery.

Of the 20 groups, all teachers believed their students learned some scientific information or something about science. All responses were in reference to the science information to which they were exposed during the DSIS programs, or about science in general. The following comment encapsulates what most of the teachers who responded expressed regarding their students' learning:

> *"Most definitely yes. We teachers with the students at CSIRO actually commented on the high level of interest by the children. They listened, interacted and were very hands-on."* *Year 6 teacher*

Their responses, about what their students' learned, are listed in Box 7 below.

Box 7: List of information learned by students, as perceived by teachers

Information learned related to:

Science in DSIS program

- biodiversity, colon cancer, cancer in general, DNA and genes, salinity issues, environmental issues,
- activities in the lab
- energy exhibit, 3D movie, handling stick insects
- what they did/learned

Science in general

- raising awareness of variety of science fields
- importance of research and implementing findings
- finding solutions to problems (economic, environmental, innovative) via scientific research
- research can be used to develop interest in science
- research needs education, scientists, support, funding
- heightened awareness of problems facing animals and scientists' work to find cure for diseases
- building on existing knowledge
- students using what they learned for 'inventions unit' at school
- broadened students' view of world

Additional Comments

Teachers were given the option to contribute additional comments at the end of the survey.

Of the 20 surveyed groups, non-response was high – eight teachers did not contribute any additional comments. The remaining 12 teachers expressed very positive comments about the DSIS programs and their students' participation in it. Overwhelmingly, teachers liked the programs; complimented the staff, activities and format, and believed that their students experienced some learning from the visit. Some of the comments from the 12 teachers who responded are listed in Box 8 below:

Box 8: Positive additional comments from teachers

Comments explicitly applied to the program:

- Good variety of activities
- Well set up and informative
- Friendly, well-informed staff
- Well organised
- Students felt voting activity had importance
- Freedom to move around ensures exciting time for students

Comments related to science in general:

- Students indicated interest in becoming scientist
- Students encouraged to look at science as career
- Awareness of research and funding procedure

Other comments suggested some level of dissatisfaction with certain elements of the DSIS program, as listed in Box 9 below:

Box 9: Negative additional comments from teachers

Comments related to dissatisfaction

- More time needed
- More discussion or debate of both voting topics and lab experiments
- Unfortunately a number of students expect to be entertained and so prefer Questacon, but they learn far less there than CSIRO, and to me, of less value.

4.4 Summary

These results offer evidence that the DSIS programs met the objectives set for them. Students demonstrated a high level of retention of information from their learning experience in the DSIS education programs. Students showed a good recollection of the CSIRO and some of the research it undertakes, as well as an understanding of the role of scientific research, its intended outcomes and benefits to society. The results also showed a high level of enjoyment of the program activities, program structure and interactions with staff. Comments by the teacher of each group confirmed that the students' recalled and enjoyed their experience at Discovery.

The final chapter discusses the findings of this research and makes some concluding comments about this research, and implications for future research in the area of science communication in the informal setting of science centres.

Chapter 5: DISCUSSION AND CONCLUSION

It is clear from previous research that learning does take place in science centres (Rennie, 1994; Hein, 2000; Falk, 2002; Dierking et al, 2004; Pedretti, 2004). However, what and how much is learned varies considerably from science centre to science centre, and is affected by myriad factors influencing that learning experience. Results from this research indicate that learning is likely to have occurred after participation in the DSIS programs and that the programs successfully satisfied the objectives set for them. The students demonstrated a high level of retention of information to which they were exposed, attested to a memorable and enjoyable experience and recalled other information about science. Students easily recalled what the CSIRO is and what it does, engaged in a decision-making process related to scientific research and seemed to become more aware of the process and sometimes complex nature of scientific research.

Findings of research by Falk & Dierking (1992) have shown there is evidence that the strongest memories of a learning experience in an informal setting is related to affective and emotional aspects of the visit. This may relate to a multitude of factors, but it is evident, as seen in research by Rennie (1994), that if visitors enjoy their science centre experience, chances are they are more likely to remember it, learn from it and be open to further learning on related topics.

Results of this research, as seen in questions 4, 5 and 6, also show a high level of enjoyment by students. Almost all student groups answered 'Yes' when asked if they liked the activities in which they participated, enjoyed the staff interaction and whether they liked participating in the role-play activity. The main reason given for their enjoyment of the DSIS programs was that they enjoyed being an active part of the process – "having their voice heard". This would support the evidence that enjoyment is likely to encourage learning within a science centre. This may also be a key factor in determining whether such programs are effective forms of science communication.

So, what was it about the DSIS programs that contributed to the students' enjoyment? Results showed that 95% of student groups enjoyed the format of the program and activities, with the most notable response being that they liked the interactions they had with staff. Some comments included that staff were friendly and knowledgeable, listened to their questions, and answered their questions in an understandable way ("without talking down to us"). Also of note were comments about enjoying the variety of activities and that the activities were fun. This would suggest that the format of the DSIS program, of changing activity approximately every 20 minutes, enhanced the enjoyment of the learning experience and increased the propensity for students to learn; if only by preventing boredom.

Students also clearly enjoyed the participatory style of the role-play activity. The most numerous responses, when asked if they enjoyed this activity, were for the act of casting a vote, and the ability to express their opinion. They liked that it gave purpose to the learning experience, and that it related to real life. A few student groups expressed difficulty in making the decision to choose between the two research projects, but also followed this with comments on the enjoyment of having to think about that decision. From this we can conclude that involving students in a decision-making task evoked enjoyment through active participation and assigning responsibility to the activity. Also, as seen in the research of Paris *et al.* (1998 p.280, in Griffin, 2004) – that a student's interest in a topic involves both feeling-related and value-related characteristics – this research also aligns with those findings.

By creating student-inclusive situations – role-play scenario, enquiry-based talks, actively encouraging students to participate in question asking and answering – students are challenged to engage in the science topic being discussed.
This engagement led students to think about the role of scientists and how scientific research translates into 'real life' by thinking about the outcomes of the research projects. This more holistic approach to understanding science research exposed students not only to the technical information about its performance, but its role within a social and cultural context. It also provided an awareness that scientific decisions and research projects can be complex situations that require much

discussion, debate and deliberation on many levels other than purely scientific, such as social and political.

Importantly, this was one of the main outcomes of this research. Group responses suggested that students may have changed the way they perceive scientific research – the type of research performed, how it is conducted, its purpose and its relevance to daily life. All student groups agreed that carrying out scientific research was important, and many of their comments suggested either a new understanding, or a confirmed understanding, about the purpose and endeavour of scientific research. Some of these comments included awareness that there are many "things" to investigate; scientific research helps people, animals, the environment and society to evolve/move forward; science is a process taking time; science is interesting; there are lots of different facets to science; more than one person usually performs research; scientific research is a difficult job; science "gives knowledge" and helps us to discover things. One comment that encapsulated this seemingly new perception of science was, [science is] "not just test tubes and science labs".

The students' comments about science seem to promote an understanding of the processes of scientific research, and the social, cultural and economic contexts within which it is conducted. The comments suggest that students may reflect on what science is and its role in day-to-day life. Presenting information about the research and some of the issues related to carrying it out seems to have fostered thought about science beyond their existing perceptions, and encouraged a positive and fresh outlook on science. It seems to have revealed a new realisation that scientific research is not as straightforward as they had understood it to be, but full of questions, considerations, decisions, and that it can be a complex process. In many cases the responses suggest that students looked upon science with new eyes, seeing research as a necessary and beneficial part of society.

As Pedretti's (2004) research informs us, issues-based exhibits stimulate and challenge the learner intellectually and emotionally in a different way to phenomenon-based exhibits, encouraging an understanding *about* science, rather than particular science concepts. Like the exhibits in Pedretti's research, we have some evidence that the DSIS programs also promote thought *about* science, rather than particular aspects of scientific knowledge. These types of exhibits and programs may actually have the additional effect of changing a student's understanding of a specific scientific concept or idea, or encourage further learning in a particular area of science, but perhaps that is for further research to investigate.

In conducting this research there were some limitations. Collecting data via survey questionnaire had its limits for garnering comprehensive and accurate responses to some questions. Also, some non-response was experienced. Therefore, a more ideal data set may have been gained from replicating the process with another sample group. However, it is clear from the results that students recalled their DSIS program experience, retaining much detail about their visit to Discovery, and so it can be concluded that these education programs are effective in communicating science information, to varying degrees, to the student participants. One teacher's view exemplified this by expressing surprise at the level of detail with which her class could recall their visit to Discovery, as they had visited 17 weeks previously. For the majority of students, it was a fleeting experience that may pass through their mind from time to time, or when reminded, however, it is apparent from both student and teacher comments that students' high degree of information retention and enjoyment expressed, it is likely that learning did take place during these education programs.

As Falk suggests, a major strength of the past decade (1994-2004) of research on learning from museums has been the description and investigation of the myriad factors that appear to influence learning from these informal settings (Dierking, Ellenbogen & Falk, 2004). He also believes that to validly understand what is or is not learned from these places, these factors need to be considered more holistically in the learning experience. Research conducted over longer time-scales is therefore likely to inform and support a clearer understanding of this learning process, providing more robust measurements of the learning experience at science centres.

One way of assessing learning from a science centre program over a longer time-scale would encompass a student's experiences before and after their visit. Presented in this paper were a number of studies (Gennaro, 1981; Kubota and Olstad, 1991; Anderson, 1994, 1999 and Rennie 1994) that concluded that previous knowledge, pre-visit preparation and post-visit activity greatly enhances the learning outcomes of a visit to a science centre. Applying this pre-visit and post-visit investigation to the DSIS education program experience would allow more comprehensive data about what role these programs have in learning about science. Further to this, longitudinal studies may provide a deeper and more enduring understanding of learning outcomes from science centre experiences. Studies including surveys conducted before and after a student's science centre visit would more accurately identify details of the learning process or possible perception change. Future research that takes into account this, and the many other factors that influence a student's learning experience in a science centre, may provide insight into any demonstrated effect from the experience on a much broader scale of a student's understanding about science.

Participation in the DSIS education programs at Discovery is just a snapshot in time of a student's journey in learning about science. As we have seen, students do learn about science from these education programs, as captured by many comments from students and teachers. Students particularly enjoyed their interactions with staff members, commenting on their ability to make scientific information understandable in their terms. This interaction and communication was facilitated by the role-play activity, which students found enjoyable. The participatory and inclusive nature of this exercise also engendered a sense of responsibility and importance in students through the decision-making process over real life issues.

An important corollary to this would be to ensure a student-focused agenda in education programs that provide students with a sense of involvement, choice or responsibility, while creating an environment that instils a sense of enjoyment. As can be seen in this research, the DSIS science education programs successfully met the objectives set for them while also demonstrating that this type of program may set up a longer-term understanding of the complex connection between scientific knowledge and its effect in the greater social context.

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Appendix 1: Survey Questionnaire

SURVEY QUESTIONS – For Students
Visit to CSIRO Discovery

Would you please ask your students to respond to the following questions as a group, not individual students. Please remind students of their visit to CSIRO Discovery but without much detail so as not to prompt the answers. Thank you.

Q1. Who is CSIRO?

Q2. What does CSIRO do?

Q3. What kinds of jobs do people do at CSIRO? (Other than Discovery education staff)

Q4. **(Very important: Please do not prompt a response)**
What do you remember doing there? Did you like doing this?

Q5. Did you like the way the Discovery education staff showed you around the exhibit and talked to you?

Yes, why? No, why not?

Q6. Did you like participating in the role-play situation and casting a vote at the end?
Yes, why? No, why not?

Q7. What do you remember about science (in general) from your visit to the Discovery centre?

Q.8. Is it important to society to conduct scientific research? Why?

SURVEY QUESTIONS FOR TEACHER TO ANSWER

Q1. Has your students' level of interest in science increased at all since visiting CSIRO Discovery?

Yes, a lot   Quite a bit   A little   No, not at all

Comments

Q2. Do your students mention their visit to CSIRO Discovery?

Yes, regularly   Sometimes   Very ocassionally   Never

Comments

Q3. Do you believe your students learned some scientific information, or something about science, from their visit to CSIRO Discovery? If so, what did they learn?

Other Comments:

Thank you for assisting in this research by completing the survey questionnaire, it is greatly appreciated.

Appendix 2: Results of Questionnaire

Results - Questionnaire answers

Student responses

Q1. Who is CSIRO?

Correctly identified (15/20)	**75%**
Science research oganisation (2/20)	**10%**
Other – mentioning science (3/20)	**15%**

Q2.What does CSIRO do?

Science research/tests/experiments – (18/20)	**90%**
Other – 2/20)	**10%**

Q3.What kind of jobs do people do at CSIRO? (Other than Discovery education staff)

Scientists/research/investigate/testing/labs/admin – (20/20) **100%**

Q4. What do you remember doing at Discovery? Did you like doing it?

Presentations/voting role-play scenario – (17/20) **85%**
• *choosing between projects, biodiversity, colon cancer, microencapsulation, listening to bird calls in exhibit, protecting the environment, voting, looking at displays, salinity display, learning about science problems*

Hands-on Lab activities – (17/20) **85%**
• *looking down microscope, making cheese, extracting DNA from onion, wearing lab coats,*

Visual media (3D movie) – (16/20) **80%**

Talks (BioClip shearing, surveillance camera) – (9/20) **45%**
• *security camera, sheep wool,*

Other activities (handling live animals) – (8/20) **40%**
• *Stick insects, turtles in tank, mice*

Other exhibits – (3/20) **10%**
Energy exhibit – lollies, virtual kitchen, grains display

Yes, liked activities – (20/20)	**100%**
No, did not like activities – (0/20)	**0%**

Q5. Did you like the way the Discovery education staff showed you around the exhibits and talked to you?

Yes, why? 19 No, why? 3 (2 of which answered Yes also)

Explained lots x 2
Explained things clearly x 4
Careful explanations in simple language
Explained things well and drew attention to things otherwise not seen

Gave lots of information
Shared their thoughts
"Know their stuff"
Very informative x 3
Answered questions well x 3
Listened to questions and answered truthfully
They made it interesting
Showed (us) how things worked
"Scientific manner, but [information] not complicated" Year 8
They listened well

Friendly/kind staff x 5
Cheerful staff
Young
Nice/friendly staff x 2
Were polite
Interacted with us
Didn't talk to us like little kids/down to us x 2
Spoke at appropriate level
They were helpful
Voice not annoying!
Did a great job

Let us touch things
Variety of topics/activities x 2
Topics were interesting x 2
We could give our opinion
Was/loved hands-on x 2
Displays were good
Fun x 2
Not boring

Specific
Experimental

Negative comments
A bit rushed x 2
Too little time to do other things x 3

Q6. Did you like participating in the role-play situation and casting a vote at the end?

Yes, Why? 18/19 (One group didn't participate in a role-play) **95%**

Explain our opinion (got to)
Liked involvement
Liked to be included
Shared opinion
Liked to make a difference
Made us feel important (to vote)
"Makes you feel like could be part of the community"
"You cared what we had to say, valued our opinion even though we are children" Fairholme Yr 7
Found out choice (of vote)
Tough choice
Hands-on activity

Better than just listen and take notes
Listen hard and make a choice
Vote was close

"Helps with life and understanding things better"
People can tell what's happening in the scientific world
So we learn and if we would like to study science we know things already
Find out more
Explains and gives solutions
Summarised what we've done in class
Were real-life situations

Fun x 2

Gave purpose to visit
Felt professional
Helps the world

No, why not? (1/19)
Not involved enough/needed debate about issues – 1

Q7. What do you remember about science (in general) from your visit to the Discovery Centre?

These included the following responses:

Activity-related
*Don't eat cheese (in lab)**
Variety of activities
New way of shearing sheep (Bioclip talk)
Extracting DNA x 3
How pills can help in some cases (microencapsulation talk?)
About saving animals
How to shear sheep without shears x2
Generation of electricity
Temperature on Earth

Research-related
A lot of procedures to got through from beginning to end of experiments
Science is a process, if mistakes are made you have to start over
It takes a long time to solve problems
It's hard to do (compared to the average day job)
Huge costs involved (in research) x 3
Lots of things are investigated
Varied
Sometimes hard to get funding for projects
It takes more than one person to do research
It needs help and support from governments, companies and even us as individual groups
Need to be intelligent
How they have something (project) to work on
How they do experiments

General – about science
Science is very important in our lives
(Science) Not just test tubes and science labs (Year 7)
Science can [?solve] practically everything
Science helps others

Science can help us
Science helps us in medical/communication and leisure ways
Science can be fun x 5
Lots of different facets
Interesting

Topic-related
Learn about microtechnology (microencapsulation talk)
Learn about bowel cancer x 3
Important to find cures
Our wildlife is dying
Didn't know insects could be dangerous
Environmental issues

Non-specific to Discovery
Physics
Biology
That we need to do our part to help the environment

1 – Non-response

Q8. Is it important to society to conduct scientific research? Why?

Yes – all **100%**

Benefit to world/society
So our modern world can expand and become more efficient
Because things-resources are running out
Preserves things for future generations
Makes society go forward
Need to keep moving forward
Find better ways of doing things
Make our world better
Helps us to do things
Helps the world
Time-saving/energy-reducing ideas
For sustainable development
People benefit from anything scientists discover

Gain knowledge
Without research, wouldn't know how to protect things
If there were no researchers we wouldn't have made the discoveries we have
World would have no answers to problems
Helps us learn more about the world
To learn more about things
So we can learn more about our environment x 2
Find reasons for things so we can fix them
To understand things better
Learn more

Health/cures
Helps find cures x 5

Helps with diseases x 2
Saves lives
Helps to discover new ways to treat/cure diseases

Solve problems
Solve problems x 2
Explains and gives solutions
So people know how things work
More inventions
Experiments in technology

Environment/animals
Keep our environment healthy
Helps with things that affect the environment
Help stop environmental damage
To destroy Patterson's Curse
Find new resources for animals
Might find new species and put out warning

Improve quality of life
It helps the quality of our well-being
Improves quality of life x 2
Makes life easier x 2

Other
When visiting the centre you understand more about science
Too many people we've got to feed them

QUESTIONS TO TEACHERS

Q1. Has your students' level of interest in science increased at all since visiting CSIRO Discovery?

Yes, a lot	Quite a bit	A little	No, not al all
2	6	12	0

Comments
Consolidated environmental issues discussed in class.
Raised interest and refer to activities of visit sometimes.
Displays were interesting
Staff member's research shown was good
Enjoyed learning/participating in current research
Could see relevance of research
More time needed - 2
Level of interest and retention of information very high
This group enjoyed all of program and the 'why is it so?' and 'How do things work?' aspect
The visit encouraged students to do own experiments in class.
Recall certain areas.
Interest in environment and biology, finding cures and animal issues and endangered species.
Some individual students' interest has increased
Most students believe their level remained the same.
Students' level of interest strong before visit

Q2. Do your students mention their visit to CSIRO Discovery?

Yes, regularly	Sometimes	Very occasionally	Never
3	8	10	0

Comments

Still discuss colon cancer
Discuss voting activity
Mention handling animals activity (stick insects and mice)
Enjoyed visit but group needed reminding of visit, some individuals had better recollection
Visit is discussed when excursion discussed.
Students do have considerable recall
Talk about diseases, space research and other issues
Talk about funding process
Greater awareness and interest in the world around them
Discussed/wrote about soon after visit but then dissipated – 3
During science class

Q3. Do you believe your students' learnt some scientific information, or something about science, from their visit to CSIRO Discovery? If so, what did they learn?

Yes – **ALL**

Biodiversity - 2
Colon cancer/cancer generally – 2
DNA - 3
Hands-on activities – 1
Energy / exhibit – 2
3D movie about CSIRO – 1
Lab activities - 2
Salinity issues – 2
Environmental issues – 2
Information about genes – 1
Handling insects – 1
Raised awareness of variety of science fields - 1
Some built on existing knowledge – 1
Appreciated wide range of research areas – 2
Importance of research - 1
Research can be used to develop interest in science – 1
Considerations about implementing research findings – 1
Students listened well, interacted and were very hands-on – 1
About finding solutions to problems (economic, environmental, innovative) via scientific research - 1
Research needs education, scientists, support, funding – 1
Really broadened students' outlook on the many fields of science – 1
Exposure to the many interesting areas of science research was great – 1
Heightened awareness of problems facing animals and scientists' work to find cure for diseases – 2
Students using what they learnt for 'inventions unit' at school – 1

Broadened students' view of world – 1
Could remember what they did/learnt in detail.

Other comments
Loved program design specific to Year 9 needs, even if visited previously.
Programs are excellent.
Friendly, well-informed staff - 2
Freedom to move around ensures exciting time for students.
The more 'hands-on' the better.
Impressed with amount of knowledge the students retained after 17 weeks.
Students enjoyed the program and felt the voting activity had importance.
Handling live animals was a highlight for some.
4 students have indicated an interest in becoming a scientist.
Some students are able to relate to science in the community and classroom
Many of our students are encouraged to look at science as a career choice.
CSIRO is a must on our annual visits to Canberra.
Presenters are friendly, welcoming and knowledgeable.
Well set up and informative.
Good variety of activities - 3
Well-organised programs - 2
Voting activity involving students in topical issues, great - 2
Awareness of funding procedure.
Lab experiments great but perhaps more focused and drawing conclusions.
Excellent program for both students and teachers
Majority of students benefit from education programs
Unfortunately a number of students expect to be entertained and so prefer Questacon, but they learn far less there than CSIRO, and to me, of less value.